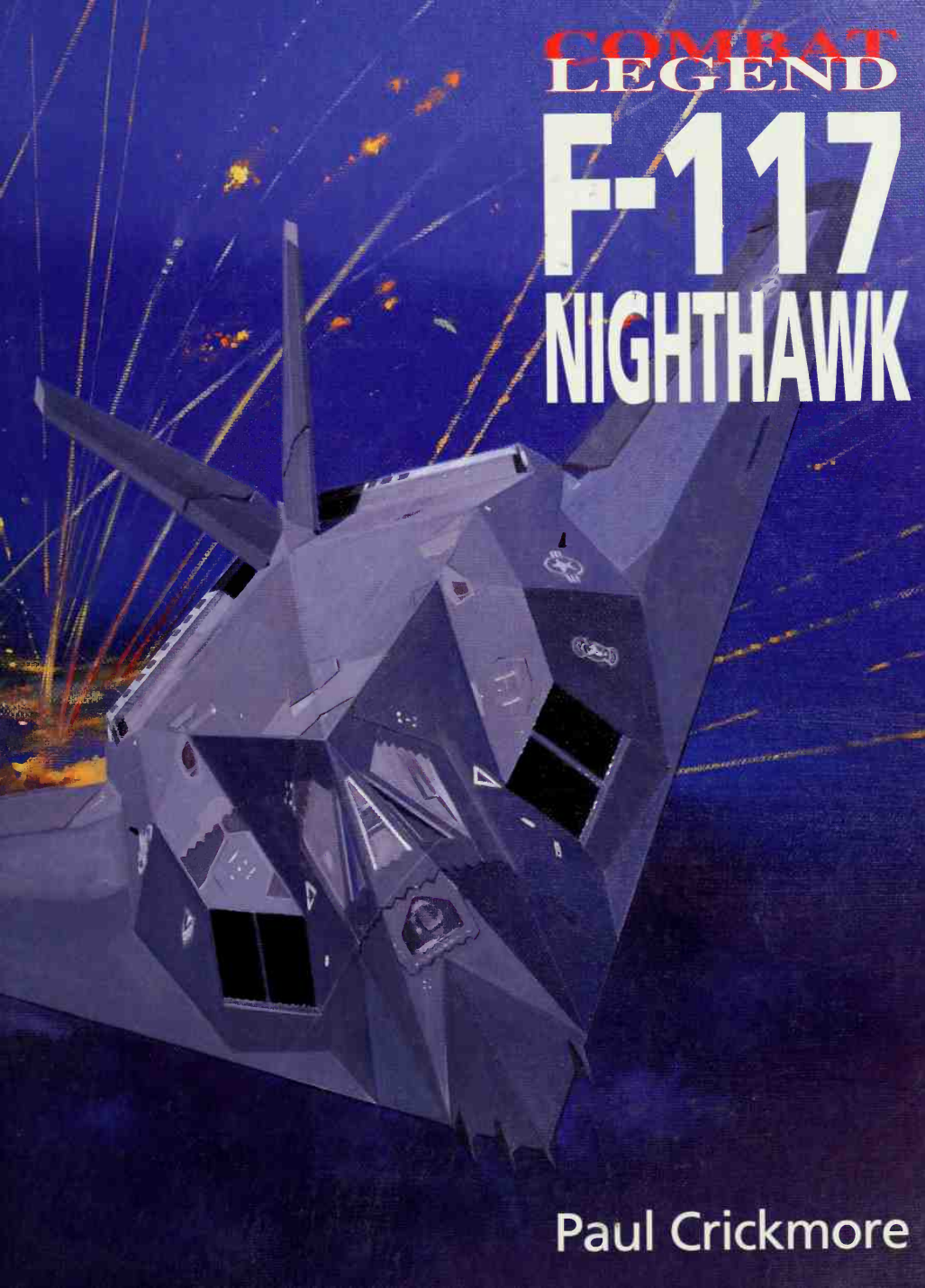
COMBAT LEGEND
F-117 NIGHTHAWK
Paul Crickmore

F-117
NIGHTHAWK

The Author
During his thirteen years at the London Air Traffic Control Centre, Paul Crickmore flew in a large number of both RAF and US Air Force fast jets. A special security clearance enabled him to fly on an operational air refuelling of an SR-71 Blackbird, flying from RAF Mildenhall in October 1981. That experience provided him with a unique access to the world of America's latest aviation technology and since that flight he has written dozens of articles and eleven books about military aviation matters.

The Cover
Thunder 36 in Desert Storm
At 0200hrs F-117A, call sign Thunder 36, took off to rendezvous with a KC-135 tanker and flew north toward Iraq. At 0230hrs the aircraft topped up with fuel and departed from the tanker to drop the first bomb in Operation *Desert Storm*. Colonel Greg Feest crossed the Iraq border and headed towards his target, an underground communications bunker southwest of Baghdad. The pilot located the target and when in range he depressed the pickle button. Seconds later the weapon bay doors snapped open and a 2,000 pound bomb dropped from the aircraft. As he watched its guided decent through the cross hairs of the laser display he saw the bomb penetrate the bunker and blow out its doors. Colonel Feest knew he had knocked out his target. He turned the aircraft 210 degrees left and looked back to see bursts of red and orange flying at him and lighting the sky. He pushed open the throttles and headed towards his second target.

The Artist
Jim Brown has spent over twenty years in the advertising industry and has been a pilot for more than half that time. His skills working with oils, acrylic and gouache, when combined with his pilot's eye for accuracy, bring an exciting new dimension to aviation art.

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F-117 NIGHTHAWK

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Airlife

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This book is dedicated to my wife Ali whose help, support, encouragement and love is a constant source of strength.

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Contents

F-117 Nighthawk Timeline

June 1975
Echo 1 computer program is developed by Denys Overholser and Bill Schroeder

April 1976
Lockheed received go ahead to build two *Have Blue* demonstrators

1 December 1977
First flight of *Have Blue*, HB1001, just after 07:00, Bill Park pilot

4 May 1978
HB1001 crashes, pilot Bill Park ejects but is badly injured; 36 test sorties completed

20 July 1978
HB1002 first flight, pilot Ken Dyson

16 November 1978
Full scale engineering development contract awarded for five FSD and 15 production aircraft

11 July 1979
HB1002 crashes, pilot Ken Dyson ejects safely; 52 test sorties completed

15 October 1979
4450th Tactical Group activated

November 1979
Assembly of the first FSD F-117 (79-10780) begins

18 June 1981
First flight of FSD F-117, '780 conducted by Hal Farley

17 November 1981
First air refuelling carried out ('780)

20 April 1982
Aircraft 79-10785 (or 79-0785) written off during take-off following maintenance error. Pilot Bob Riedenauer survived but badly injured

15 July 1982
First flight of first production aircraft conducted by Hal Farley

15 October 1982
Major Al Whitley becomes first operational pilot to fly the F-117

25 September 1985
Aircraft 79-10781 suffers rudder loss

11 July 1986
Aircraft 81-10792 crashes near Bakersfield, California. Pilot, Major Ross E. Mulhare, is killed

September 1986
10,000 flying hours achieved

April 1987
10,000 flights completed

14 October 1987
Aircraft 85-0815 crashes at a Nellis gunnery range. Pilot, Major Michael C. Stewart, is killed

20 October 1987
A 4450th A-7D crashes into a hotel near Indianapolis airport. Pilot Major Bruce L. Teagarden ejects safely, however, nine killed on the ground

10 November 1988
Assistant Secretary of Defense J. Daniel Howard reveals photograph of F-117 during a Pentagon press conference

20 December 1989
Two F-117s become the first to be used in combat during Operation *Just Cause*

21 April 1990
First declassified photos released of F-117

12 July 1990
Last production F-117 delivered

21 August 1990
First 18 F-117s arrive at King Khalid AFB, Saudi Arabia

17 January 1991
Greg Feest drops the first bomb of the campaign from an F-117, signalling the start of *Desert Storm*

November 1994
60,000 flights completed

December 1994
100,000 flying hours achieved

24 March 1999
F-117As committed to Operation *Allied Force*

27/28 March 1999
F-117A 82-0806 shot down by Serb forces during the course of *Allied Force* operations. Pilot ejected and was rescued, unharmed, by helicopter

1. Prototypes and Development: *Have Blue*

Development of a survivable interdictor has for years been the holy grail of military aircraft design engineers. The use of speed, high altitude, low altitude, agility, electronic countermeasures (ECM) and latterly, combinations of the aforementioned, has produced throughout aviation history some classic aircraft types, which, in their day, have provided air forces throughout the world with useful operational advantages, albeit at times, extremely brief advantages. Air battles fought by the United States in South-East Asia during the late 1960s and early 1970s, together with the losses suffered by Israel during the so called Yom Kippur War of 1973, were responsible for the Defense Advanced Research Projects Agency (DARPA), initiating conceptual studies into a different approach to an enduring problem; namely, whether it was possible to develop a manned aircraft with a sufficiently low radar cross-section (RCS) to defeat modern air defence systems. Consequently, in 1974, Ken Perko of the Tactical Technology Office (TTO) at DARPA requested submissions from Northrop, McDonnell Douglas, General Dynamics, Fairchild and Grumman addressing two considerations:

1. What were the signature thresholds that an aircraft needed to achieve to become essentially undetectable at an operationally useful range?

Area 51 is probably the best known 'secret' base in the western world. Situated approximately 161 km (100 miles) north-west of Las Vegas, its exceptional remoteness makes it the perfect site for black world flight test operations. *(James Goodall collection)*

Above: Ben Rich joined Lockheed in 1950; while President of the Skunk Works, he fully backed the concept of Stealth, becoming in the process 'The father of stealth'. Ben died on 5 January 1995.

Mathematical genius Denys Overholser was the powerhouse behind the Echo 1 development team. *(both Lockheed Martin)*

2. Did those companies possess the capabilities to design and produce an aircraft with those necessary low signatures?

Fairchild and Grumman declined the invitation to participate, while General Dynamics emphasised the continued need for electronic countermeasures and provided little substantive technical content regarding signature reduction. The submissions from McDonnell Douglas and Northrop, however, demonstrated a grasp of the problem, together with a degree of technical capability for developing an aircraft with a reduced signature. Consequently, both companies were awarded contracts worth approximately $100,000 each during the closing months of 1974 to conduct further studies. These studies, classified 'Confidential', also involved radar experts from the Hughes Aircraft Company whose role would be to identify and verify appropriate RCS thresholds.

At this early stage, Bill Elsner was the primary US Air Force technical expert on the programme, and at the beginning of 1975, McDonnell Douglas had identified likely RCS thresholds that could produce an operational advantage; these were

later confirmed by Hughes and in the spring they were established by DARPA as goals for the programme. DARPA then challenged the study participants to find ways of achieving them.

On 17 January 1975, Ben Rich became the President of Lockheed's famous Skunk Works. Having joined the company as an entry-level engineer, in 1954 he began working on the U-2. Five years later, he and Dave Campbell were principal propulsion engineers on Project Gusto, a series of design submissions that would evolve into the legendary SR-71. In truth, Ben had inherited an awesome task, as post-Vietnam, defence spending was at an all-time low and the year before his appointment, a bribery scandal surfaced, in which Lockheed executives admitted paying millions of dollars in bribes, over more than a decade, in order to secure contracts, principally for the F-104 Starfighter, from key officials and politicians in The Netherlands, West Germany, Italy and Japan. As if that was not bad enough, Lockheed's attempt to re-enter the commercial airliner world with its L-1011 TriStar failed spectacularly and plunged the company into financial turmoil. In 1972, Congress reluctantly helped bail out the company with loan guarantees of $250 million, however losses continued to accumulate and by late 1974 these had reached a staggering $2 billion.

Finding new business

Fifty-year-old Ben's first task was to get new business fast and fill as much of the 27870 m^2 (300,000 sq ft) of production and assembly space in the two enormous hangars at Burbank as possible. His course of action was to convince General David Jones, the Air Force Chief of Staff, of the need to re-open the U-2 production line – a game plan without precedent – since never in its history had the USAF restarted a production line for any aircraft in its inventory, let alone one whose tooling had been placed in storage six years earlier. However, during that meeting General Jones indicated that he was 'favourably disposed' to the idea, but Ben was under no illusions, to secure the long-term future of the Skunk Works, what was needed was a substantial project involving revolutionary technologies. (Interestingly, however, on 16 November 1979, the Skunk Works received an Air Force initial contract worth $10.2 million, for the refurbishment of Palmdale's U-2R production facilities (Air Force plant Number 42). Over the next ten years this facility produced 37 U-2Rs – initially designated (for political reasons) as TR-1s, for Tactical Reconnaissance.)

A-12/D-21 heritage

It was while Ben was still 'Kelly' Johnson's deputy, that the former became aware of the low observability study. Lockheed had not been one of the five original companies approached by the DARPA team, simply because it had not produced a fighter for nearly ten years. However, while networking his contacts at the Pentagon and at Wright-Patterson AFB, Ed Martin, Lockheed California Company's Director for Science and Engineering, was made aware of the study. He and Ben then briefed Kelly, who in turn obtained a letter from the Central Intelligence Agency (CIA), granting the Skunk Works permission to discuss with DARPA the low observable characteristics of the A-12 and D-21. Ben and Ed then presented the results to Ken Perko and Dr George Heilmeier, the head of DARPA, and formally requested entry into the competition. Dr Heilmeier, however, explained that two $100,000 contracts had already been awarded to two companies and there was no more cash available. After much negotiating and horse trading, Ben managed to convince the DARPA boss to allow Lockheed into the competition without a government contract – a move that ultimately paid a handsome divided. Lockheed was then given access to technical reports already provided to the other participants and the first step that would culminate in a revolutionary aircraft was taken; Lockheed's new President, Larry Kitchen, supported Ben, securing from the Board the necessary capital for the project.

In February 1975, Dick Scherrer joined Ed Martin from Lockheed's white world (not classified), Advanced Concepts Department. He

made enquiries within the Skunk Works to unearth any theoretical foundations on which he could base a low RCS design. His investigations drew a blank, however he was introduced to Denys Overholser.

Mathematical conundrum

Denys had joined the Skunk Works from Boeing in 1964. He recalls: 'When Dick Scherrer asked me, "How do we shape something to make it invisible to radar?" I said, "Well, it's simple, you just make it out of flat surfaces, and you tilt those flat surfaces over, sweeping the edges away from the radar view angle, and that way you basically cause the energy to reflect away from the radar, thus limiting the magnitude of the return."' The framework for such radical thinking had its roots in discussions that Denys had had years earlier with his then boss Bill Schroeder. Bill, a brilliant mathematician, had been employed by Kelly to resolve analytical problems, and had trained Denys. During the course of discussing the mathematics and physics of optical scattering, the two had concluded that detectable signatures could be minimised utilising a shape composed of the smallest number of properly orientated flat panels. In addition, Denys' boss believed that he could develop and resolve a mathematical equation capable of calculating analytically, the reflection from a triangular flat panel; this in turn could be applied to a calculation relating to RCS.

With an input from Denys, Dick Scherrer drew a preliminary low RCS shape based on a faceted delta wing. By April, Denys had hired his ex-boss, Bill Schroeder, out of retirement and they set about completing solutions to RCS equations that would enable the group to predict results. Scherrer recruited Kenneth Watson as Senior Lead Aircraft Designer, with the mandate to fit systems inside the 'shell' that he and Denys were designing.

As the design effort continued, Bill Schroeder's mathematical computations became available; Denys Overholser and his team of two engineers then used these to write the computer programme that could evaluate the RCS of prospective design submissions nominated by Dick Scherrer and his group of preliminary design engineers. Denys and his team worked night and day, and in just five weeks produced an RCS prediction program known as Echo 1. However, as tests continued, it became apparent that the edge contributions calculated by Echo 1 were not accurate, owing to a phenomenon known as diffraction. Incredibly, the solution to the problem was provided by a Soviet scientist. The Skunk Works team was made aware of a publication entitled *Method of Edge Waves in the Physical Theory of Diffraction*, published in an unclassified technical paper by Pyotr Ufimtsev, Chief Scientist at the Moscow Institute of Radio Engineering. The paper had been translated by Air Force Systems Command's Foreign Technology Division in 1971, and Denys was able to incorporate elements of its theory into a refined version of the Echo 1 program and use this to mathematically evaluate over 20 designs to identify the one with the smallest RCS. The faceted delta wing design had more than its share of sceptics within the Skunk Works, some in aerodynamics referred to the shape as the 'Hopeless Diamond'.

Lockheed then produced two 1:3 scale wooden models of the Hopeless Diamond. One was used by the aerodynamicists in wind tunnel tests, the other was coated with metal foil to provide a conductive surface and used to measure RCS in Lockheed's anechoic chamber. The first series of tests was conducted in June 1975, and they demonstrated that the RCS 'spikes' matched precisely those predicted by Echo 1. The model was then moved outdoors to a radar test range near Palmdale, on the Mojave Desert. Owned by McDonnell Douglas, the Grey Butte Range, boasted improved capabilities, enabling the team to measure even lower RCS values, and yet again these test results conformed well with Echo 1 predictions, creating greater levels of confidence in both the computer program and the faceted design concept.

To improve the vehicle's lift-to-drag ratio, the section outboard of the engine inlets was thinned, resulting in the semblance of wings, which were eventually extended outward, changing the

planform from the original diamond shape, to a notched-out delta. The trailing edge sweep was increased to 48° to ensure that the signature spike associated with the trailing edge fell outside the frontal sector, to minimise 'nose-on' detection, and inboard canted tail surfaces were also added.

DARPA proposals

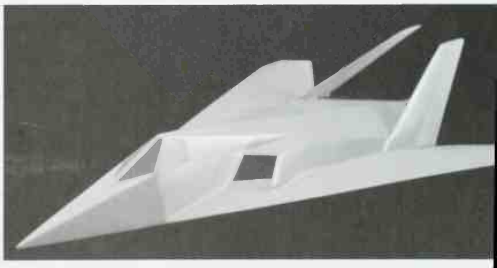
Two proposals were submitted to DARPA from Lockheed, one included the predicted and measured signature data for the Hopeless Diamond, the other provided the predicted data for an air vehicle of flyable configuration. This came about in response to DARPA issuing proposals to the three competitors for what was to become known as the Experimental Survivable Testbed (XST) programme. This was informally requested in the late summer of 1975 and responses were due in August or September, wherein the signature goals were those laid down in the earlier 1974–1975 Directive.

Northrop's XST entry was similar in appearance to that of Lockheed's. Its design had been developed from a computer program called GENSCAT, which also had its origins in mathematical equations associated with the physics of optics. Like Lockheed, Northrop used computer modelling and the Grey Butte Range to test and evaluate its design. By the summer of 1975, it too, had reliable indications that its design would achieve the RCS goals set earlier.

Having been the first to determine what the RCS thresholds for the competition were likely to be, McDonnell Douglas was unable to design an aircraft that could achieve anything like those goals. With RCS results coming from both Lockheed and Northrop verging on the revolutionary, Ken Perko called a meeting within DARPA to determine the programme's future direction. It was decided that the programme should be developed still further, into a full-scale flight test demonstration, consisting of two phases. Phase 1 would culminate in a ground RCS evaluation of large-scale models. Following this, one contractor would be selected to proceed with Phase 2, the construction and flight testing of two demonstration vehicles. The estimated cost for the XST programme was $36 million and this would be split between the successful contractor, a reluctant Air Force and DARPA; with the latter contributing marginally more, thereby retaining programme management control. By August 1975, funding arrangements were completed and on 1 November 1975 Lockheed and Northrop were awarded contracts of $1.5 million each to conduct Phase 1 of the XST programme.

The two companies were each given just four months to complete the initial phase of the competition, which involved the construction of full-scale, wooden test models, which would then be evaluated at the Air Force's Radar Target Scatter (RATSCAT) test range, located at White Sands, New Mexico. It was already apparent that the RCS results achieved by both participating companies were unlike anything obtained before; it was even necessary to develop a new, low-signature pylon so that returns from the pylon did not impinge upon results from the models.

In March 1976, the Lockheed model was hauled by truck to RATSCAT and the testing began. Throughout the tests the competing contractors and their models were kept in isolation from one another, billeted in temporary quarters affording each independent access to the range. In early April 1976, Lockheed received word that it had officially won Phase 1 of the competition. However, the outstanding results achieved by



This early model of *Have Blue* depicts the extreme nose to wing tip leading edge sweep, together with highly faceted surfaces. *(Lockheed Martin)*

Northrop caused DARPA to urge that the team remain together. Shortly thereafter, DARPA initiated studies into a Battlefield Surveillance Aircraft, Experimental (BSAX), which evolved into *Tacit Blue* – the highly successful flight demonstration programme that provided vital data for the subsequent Northrop Grumman B-2 Spirit bomber programme.

Phase 2 of the XST programme became known as the *Have Blue* programme. It began on 26 April 1976, with the Skunk Works authorised to proceed with the design, construction and flight test of two demonstrator aircraft. To build *Have Blue*, Rich needed to raise $10.4 million and recalled: 'One can't imagine what goes through your mind when you have to ask the Board of Directors to invest $10.4 million, at a time when the Corporation was considering bankruptcy.' Contract negotiations were completed two months later and a first flight was planned for December 1977.

This *Have Blue* RCS test model is seen in Lockheed's anechoic chamber at Rye Canyon. *(Lockheed Martin)*

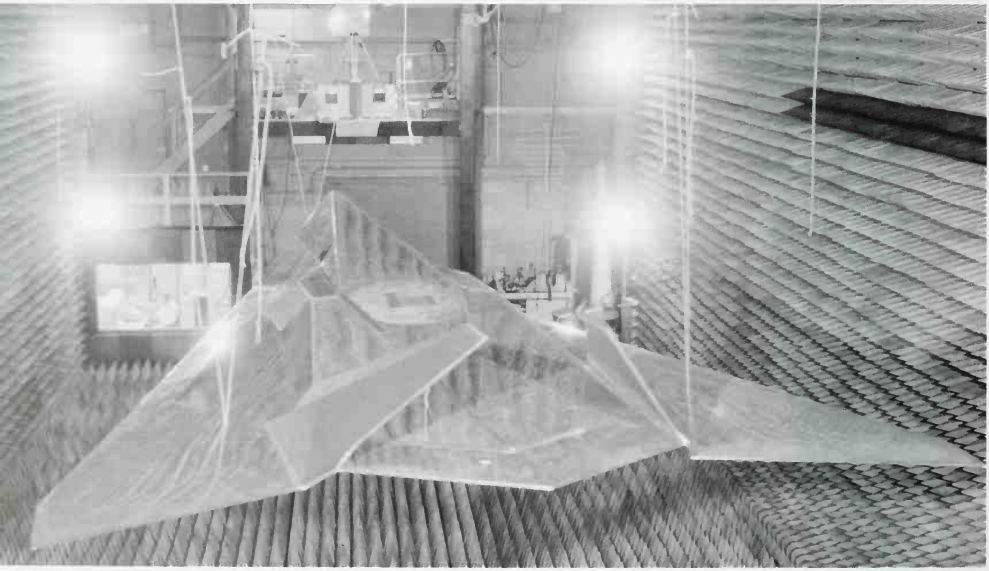
There were three objectives to the *Have Blue* programme:

1. To validate, in flight, the four low-observability signatures identified earlier in the programme (radar, infra-red, acoustic and visual).
2. To demonstrate acceptable performance and flying qualities.
3. To demonstrate modelling capabilities that accurately predict low-observable characteristics of an aircraft in flight.

Have Blue

The manufacturing of *Have Blue* was placed under the direction of Bob Murphy and the entire Engineering, Fabrication and Assembly of the two aircraft was carried out in Building 82 (birth place of the F-104, U-2 and A-12).

Just four assembly tools were used on the project, these being for the wing, forward fuselage, aft fuselage, and boom and stub fin assembly sections. The subassemblies were all made on a tooling plate left over from where the main frames for the C-5 Galaxy had been machined. Templates



Early during Phase 1 of the XST programme, it became apparent that results from the mathematical model and RCS testing were revolutionary. *(Lockheed Martin)*

were laid on the plate and subassemblies were built by hand.

By early 1977, the government realised what a major breakthrough had been achieved in Very Low Observable (VLO) technology and what a radical impact the successful deployment of such techniques could have on national defence. Subsequently, programme security migrated from the white world minimum security classification of Confidential, into the black world, where the programme became Top Secret, 'special access required' (SAR).

Off-the-shelf equipment

To reduce time, costs and risk in this revolutionary project, a Tactical Air Command major, Jack Twigg, was cleared into the programme and became the System Program Officer (SPO), whose remit was to procure, wherever possible, tried and tested, off-the-shelf pieces of equipment which would then be delivered in Building 82, where the *Have Blue* aircraft were being built, via circuitous, covert routes, in order to retain security.

The two *Have Blue* machines were single-seat, subsonic aircraft, each powered by two 13.12-kN (2,950-lb st), General Electric J85-GE-4A non-afterburning engines. Six engines were acquired for the programme from the US Navy's North American T-2B Buckeye trainer stores. The only modification made to the engines was the addition of coating to the spinners.

Have Blue was 14.40 m (47 ft 3 in) long, 2.30 m (7 ft 6½ in) high and had a span of 6.86 m (22 ft 6 in). Its modified delta wing planform, had a sweep of 72° 30', creating a wing area of 35.86 m^2 (386 sq ft). No flaps, speed brakes or high lift devices were incorporated into the structure, which was built mainly from aluminium alloy, utilising steel and titanium in the hot areas. Aerodynamic control was achieved by ailerons, located inboard on the wings, and by two all moveable fins that were canted inboard about 30°. Flight control actuators were the same as those used on the General Dynamics F-111. A small side stick controller (a stock YF-16 component) and conventional rudder pedals, enabled the pilot to operate the control surfaces. The external shape evolved from VLO and controllability considerations, the fall-out from which was a relaxed static stability (RSS) aircraft, which required a quad redundant fly-by-wire (FBW) flight control system (FCS) to keep the aircraft flyable throughout the flight envelope. The FBW system that provided stability augmentation was made by LearSeigler (also F-16 stock); there was no mechanical back-up.

During the course of aerodynamic tests conducted by the Skunk Works on free-flight models, it was determined that the large leading edge wing sweep produced considerable nose-up pitch moments, actually causing pitch departure when 17° angle-of-attack (AoA) was exceeded. To prevent such events occurring on the two *Have Blue* aircraft, elevon 'nose down' pitch control was augmented by a large, two-position flap which comprised the trailing edge of the exhaust deck. Called the 'platypus', it automatically deflected downward whenever 13° AoA was exceeded. The 'platypus' flap then retracted automatically after the pilot reduced the aircraft's AoA.

Externally, the two *Have Blue* aircraft differed from one another. The prototype, HB1001, was equipped with a large flight-test nose boom and a drag 'chute, unstealthily mounted, in an external

Despite the programme ending in the summer of 1978, only a handful of *Have Blue* photographs have ever been released. HB1001 is depicted here resplendent in its unique camouflage pattern. *(Lockheed Martin)*

box on top of the fuselage; the reason being that primarily its career would validate aircraft handling qualities and stability and provide test data. Its sister ship, HB1002 was designated as the RCS test vehicle. The gross weight of the aircraft ranged from 4173 to 5670 kg (9,200 to 12,500 lb); zero fuel weight was 4060 kg (8,950 lb) with 1588 kg (3,500 lb) of fuel being carried in fuselage and wing tanks.

VLO requirements resulted in the design of a unique exhaust system. To prevent radar energy from penetrating to, and reflecting back from, the turbine face, the tail pipe was transitioned from a round duct to a 17:1 flattened slot, convergent nozzle. Bypass air was also passed over the tail pipe to cool the aft fuselage structure thereby reducing the IR (infra-red) signature.

Major Norman 'Ken' Dyson, was selected as the USAF pilot on the project and he worked closely with Bill Park, Lockheed's chief test pilot on *Have Blue*. Prior to the aircraft's first flight the two pilots spent many hours in the simulator, which was located at Lockheed's Rye Canyon facility.

Owing to an industrial dispute, HB1001's first flight, scheduled for 1 November 1977, slipped. In the event, it was not until the early morning rush hour of Wednesday 16 November, that the disassembled and crated *Have Blue* prototype was flown out from Burbank to its secret test site at Area 51, in the belly of a C-5 Galaxy. On arrival at Area 51, the aircraft was reassembled and four low- and high-speed taxi tests were conducted. During the third test the brakes overheated, causing the wheel fuse plugs to melt, but following the fourth test *Have Blue* 1001 was cleared to fly.

Preparing for flight

During the night of Wednesday 30 November the aircraft was prepared for its first flight. The next day, just after 07:00, Bill Park got the machine airborne. In spite of a strong headwind, the take-off run was long and the climb-out sluggish, owing to the aircraft's low lift-to-drag ratio and its low thrust-to-weight ratio. Additional power loss was also associated with the inlet grids and the engine exhausts. The gear remained extended to avoid retraction problems and the flight was completed satisfactorily. Thereafter, Bill completed the first five test sorties, before Ken flew the aircraft for the first time on 17 January 1978; after which the two alternated duties between flying chase in a Northrop T-38 Talon and exercising HB1001.

During this phase of flight testing, aircraft Number One's FBW computers were fine-tuned, thereby improving the vehicle's handling characteristics. Many of these characteristics had been accurately predicted during some 1,500 hours of wind-tunnel testing. For example, the lack of directional stability, due to the highly swept wing, which became greater with increasing

AoA, was predicted, so too the rolling, pitching and yawing moments, produced during pilot inputs to the prominent, inboard cant of the twin tail units. The resultant effects of thrust generated from the aircraft's unique slotted exhaust nozzles did, however, produce some discrepancies in relation to its predicted lateral/directional characteristics. Directional stability was less than that predicted and above 0.65 Mach, the aircraft became directionally unstable. Side forces, due to side-slip, were less than half the predicted values, however, these problems were rectified by changing yaw gain in the flight control system.

By 4 May 1978, Bill had successfully completed 24 flights on HB1001 and Ken had notched-up 12; the aircraft had performed well throughout the flight test programme, which was now virtually over. That day, as Bill crossed the runway threshold at about 113 kt (209 km/h; 130 mph), descending at a gentle 0.30 m (1 ft) per second, the movable 'platypus' extended linearly as advertised, to ensure that the AoA remained within safe limits. Suddenly, when three or four foot above the runway, the aircraft pitched downward. Skillfully, Bill managed to get the nose up, but the aircraft impacted the runway hard, starboard main gear first. Now with both mains on the deck, the flight control system logic again worked as designed and rapidly fully retracted the 'platypus'. This however caused the aircraft to pitch into a high AoA. Nevertheless, Bill managed to get the aircraft back under control, increased power, called that he was 'going around' and instinctively retracted the undercarriage. Unfortunately, the starboard gear leg had been bent during the runway impact and then steadfastly refused to extend from the wheel well, despite Bill flying several circuits and hitting the runway hard in an attempt to shake it loose. When this failed, he began climbing the aircraft to 3048 m (10,000 ft) in readiness to eject. Shortly thereafter, the engines flamed-out due to lack of fuel and Bill ejected a little earlier than planned. As Bill descended in the 'chute, the T-38 chase aircraft with Larry McClain in the front seat and Ken Dyson in the back, flew circles around him, as did the base rescue helicopter. They could see that he

Have Blue 1002 was the RCS test vehicle and was flown throughout its life by Lt-Col 'Ken' Dyson. Note the conventionally shaped undercarriage doors. These were subsequently redesigned for the *Senior Trend* programme. *(Lockheed Martin)*

was in trouble and appeared to be unconscious as he hit the desert floor. He was quickly recovered by a paramedic and taken to hospital where he later regained full health. However, having received concussion, Bill's flight test career was over. Consequently, he was named by Ben Rich as Lockheed's non-flying chief pilot.

Have Blue 1002 modified

Have Blue 1002, was substantially complete, but not ready for flight. Further modifications were carried out on the basis of lessons learned on the aircraft's recently departed stablemate. This included re-building the aft fuselage, modifying the 'platypus' and adjusting the FCS. Air Force pilot Major Russ Eastor, was directed to join the team and Ray Gowdy was also recruited as a back-up pilot from Lockheed. Both men provided superb support for the remainder of the *Have Blue* programme, but neither would actually fly the aircraft; all flights on aircraft Number Two, would be made by Lt-Col Ken Dyson.

Early on the morning of 20 July 1978, all was at last ready for HB1002 to take to the air. Ken recalls: 'The unstick was about 125 kt [232 km/h; 144 mph], and the climb speed likewise was slow around 250 kt [463 km/h; 288 mph]. Russ and Ray were in the chase T-38s for that first flight which lasted only four tenths of an hour. We flew with less fuel onboard, so that it wouldn't be heavy in case I needed to land immediately after take-off. The flight consisted of basic aircraft airworthiness, systems checks, flying quality checks, flight control system evaluation and of course, it was a fully instrumented data-collecting flight; we wanted to make sure that everything was right with the bird. We did not fly too high or go too fast, I guess about 20,000 ft [6096 m] and 250 kt. The airplane performed just fine, we had a nominal flight and we were all pleased to get the bird back on the ground and through its maintenance recovery and preparation. I do recall the dinky brakes we had on that airplane, and on airplane Number One. It was designed that way and it was all the brake we could stick in the wheel. After every flight, at the end of the landing roll, the brakes would just be glowing cherry red! Sometimes our maintenance crew were waiting with cooling fans to put on them to keep them from melting down. I don't recall that there were any write-ups on that first flight, I believe the callsign was BANDIT ONE.

'We flew three flights to check the airplane out; flight control systems, the hydraulics, the engine and the data-collecting system, to make sure that we had a good airplane. Then, on the 9th August 1978, we began to take the first airborne RCS measurements. Earlier flights on airplane One were associated with airworthiness testing. In fact, as far as I'm aware, it was the first time anyone had ever attempted to measure the RCS of a manned airplane in flight. I flew against a ground-based facility and on these first series of tests they wanted to check out the cross-section of the airplane nose-on, that's with a look angle of zero. To achieve this I climbed to a predetermined altitude and maintained a heading that would take me right over the radar test site. When I reached the test point, I configured the airplane in a descent, making sure my speed, angle-of-attack and rate of decent was exactly correct. I had to keep control movements to a minimum in order to provide accurate test data, so I switched in the autopilot. Well, as soon as I did that, the nose went right and the wing rolled slightly left. I latter learned that Ben Rich, who was watching the test in the radar control room went crazy, asking, "What does that god-dam Air Force pilot think he is doing. Is he deliberately side-slipping the airplane to screw-up our test results!" I decided to switch off the autopilot and fly manually, something we'd planned not to do, because the test engineers didn't think a man could achieve the necessary tight parameters. Well, it seemed to work pretty good and after that, I flew all the tests manually – we never did resolve the problem with the autopilot. Virtually every flight in airplane Two, was associated with RCS measurements and if we weren't measuring radar returns, we would be flying the airplane against operational systems to see if they could see us; to my knowledge, none did.

Prior to his appointment as the USAF project pilot on *Have Blue*, Major 'Ken' Dyson spent some time as the programme director for the F-15 Eagle. *(US Air Force)*

'By 29 June 79, we had flown against every system operationally that we could think of and we had measured the airplane every possible way; actual in-flight measurements, to see what the airplane really looked like. That day, shortly after take-off, I noted that one of the hydraulics systems was acting a bit strange. The pressure was oscillating somewhat and going down, so I air aborted directly back and had the guys work on it. On 10 July, we flew again and the airplane was OK. The next day I got airborne and had the chase airplane look me over. Everything was OK, so I flew outbound to get to a point to run against an F-15 Eagle, to see how it performed against us. I was just short of the designated turn point, when I noticed the same hydraulic system begin to oscillate, again in the downward direction. I thought well, that's the end of this flight and turned back. I started to tell test control about my problem, when I got a fire light. After pulling the power back, and telling them of my troubles, I shut the engine down. All this was in short order. I had the airplane pointed towards home plate and configured at the right speed for single-engine operation (it was not a good performer on a single engine, not much thrust, and a lot of drag). I was coming home somewhere between 20,000 and 25,000 ft. Shortly after that the remaining hydraulic system began to oscillate in a downward direction and I knew that was not good for our unstable machine. Just about the time the remaining hydraulic system went to zero, the plane pitched violently down, something like 7 negative *g*s, it then pitched up. The pitch rates were just eye watering, something only an unstable machine could do. I was somewhere around 225 kt [417 km/h; 259 mph] and above 20,000 ft [6096 m] and the airplane was tossing me up and down and actually got near vertical nose down and near vertical nose up. I began to try and reach for the ejection seat ring that was between my legs. I got my hand on it and pulled. The canopy blew off, the seat went out and I found myself floating under a 'chute at about 20,000 ft. I had noted my take-off time, and while hanging in my 'chute I noted that ten minutes had elapsed from take-off. I watched the unstable machine flip flop slowly it seemed, as it descended vertically below me and I saw it hit the ground and erupt into a ball of fire, it still had a lot of gas on board. It took me quite a while to make my parachute descent down to the desert floor, after landing (that was my first and only jump to date), I again noted the time, I had been in the parachute for ten minutes.'

As Ken slowly descended by chute, the pilot of the F-15 with which he had planned to conduct further tests, began orbiting above. Col Norm Suits, the Director of the F-15 Joint Test Force, saw the stricken *Have Blue* aircraft impact the ground and shortly afterwards, spotted two unauthorised

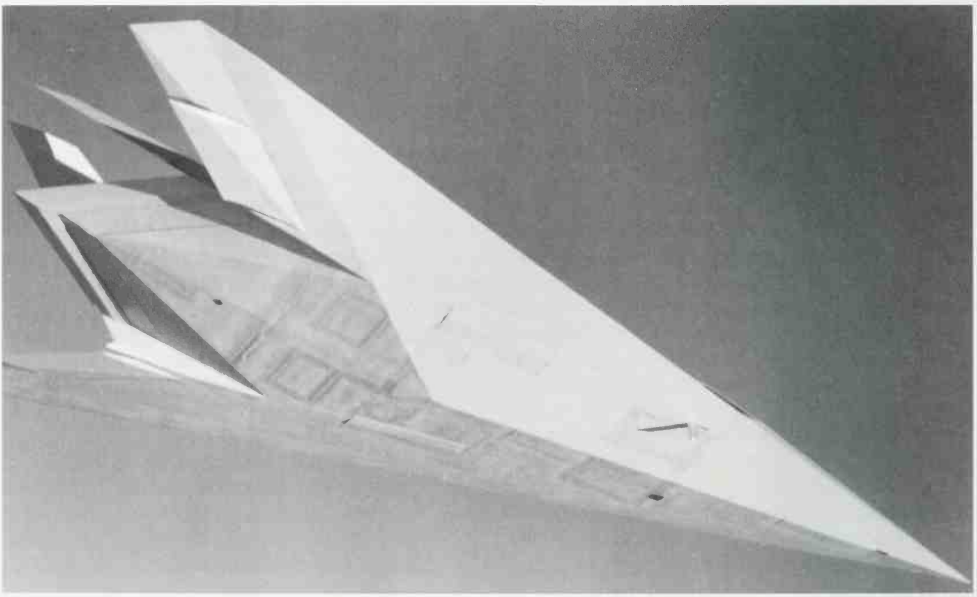
cross-country vehicles heading towards the crash site. Although the vehicles' occupants were probably intent on performing their public duty and offer help and assistance to any survivors, the highly classified nature of the programme and the materials used in its design could not be compromised. Acting on his own initiative, Norm began a series of extremely low passes at the vehicles to deter their drivers from closing on the wreckage. Just how low these passes were, can only be judged from the fact that he succeeded in his objective!

Ken continues: 'I stood up, but my back was hurting, so I got back down and used my survival radio to talk to the rescue chopper. Those guys put me on a stretcher, carried me to the chopper and took me to hospital for some treatment. I was in hospital for just one night and was then released. I was flying again within a couple of weeks, but my back was still sore. Eventually, the Docs figured that I'd sustained three vertebrae compression fractures – no wonder my back was sore!'

The cause of the crash was determined to be an engine exhaust clamp, which had become loose, allowing hot exhaust gasses to enter the right engine compartment. This had triggered the fire warning light and as the temperature built up, first the left and then the right hydraulic lines failed, which in turn caused a complete loss of control. Ken believes that the aircraft didn't actually catch fire, but that the fire light had illuminated owing to the hot gasses in the engine compartment.

Fortunately the programme was within two or three sorties of its planned completion, which officially came in December 1979. Having achieved all its test objectives, the *Have Blue* programme can be categorised as a stunning success; the next step was to determine how the demonstrated technology could be integrated into an operational weapons platform.

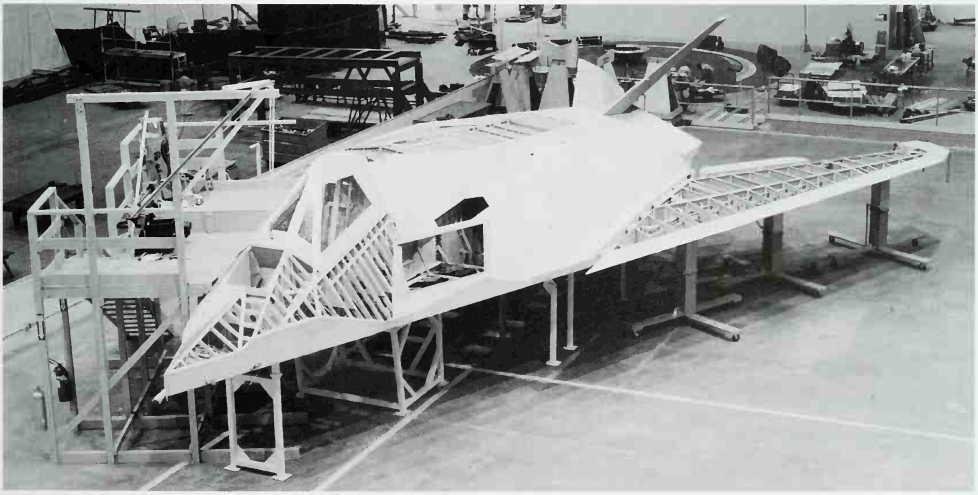
One of the few shots of *Have Blue* in flight to be released. Note the slot into which the forward-folding blade antenna retracts. *(Lockheed Martin)*



2. Operational History: *Senior Trend*

In June 1977 the Air Force set up a special project office in the Pentagon. Its objective was to exploit low observable technology then being demonstrated in Phase One of the XST programme. The small team commanded by Col Dave Williams and consisting of Majors Jerry Baber, Joe Ralston, Ken Staten and Bob Swarts, reported directly to the Deputy Chief of Staff for Research and Development, Lt-Gen. Alton D. Slay.

In addition to initiating conceptual studies into a manned strike aircraft programme, referred to



Construction of a wooden mock-up began on 1 January 1979 and was completed eleven months later on 3 December. Functional engineers then used the assembly to determine the location of various aircraft subsystems. *(Lockheed Martin)*

Construction of all 60 F-117As took place within the Skunk Works facilities at Burbank. Machining was carried out at Plant C1, sheet metal fabrication at Building 82 and final assembly (seen above) at Buildings 309 and 310. *(Lockheed Martin)*

as the Advanced Technology Aircraft (ATA) programme, the team also identified the need to develop, in parallel with the XST programme, methods of locating, tracking and striking targets in a way commensurate with maintaining a VLO profile. In response to a request for further information from Gen. Slay, a nine-point document was provided to the SPO from Air Force Systems Command, which outlined various stealth-driven programmes that would comply with such criteria (one particular line item referred to the development of a forward-looking infra-red (FLIR) turret).

Two sets of preliminary requirements for the ATA were developed; ATA 'A', a single-seat attack aircraft, with a 5,000-lb (2268-kg) payload and 400-nm (741-km/h; 460-mile) range; and ATA 'B', a two-seat bomber with a 10,000-lb (4536-kg) payload and 1,000-nm (1853-km; 1,151-mile) range. An $11.1 million concept-definition contract was awarded to the Skunk Works on 10 October 1977, for a one-year study based on the two sets of requirements. The engine selection process began on 17 January 1978, and 11 days later a wind tunnel programme was inaugurated with test results

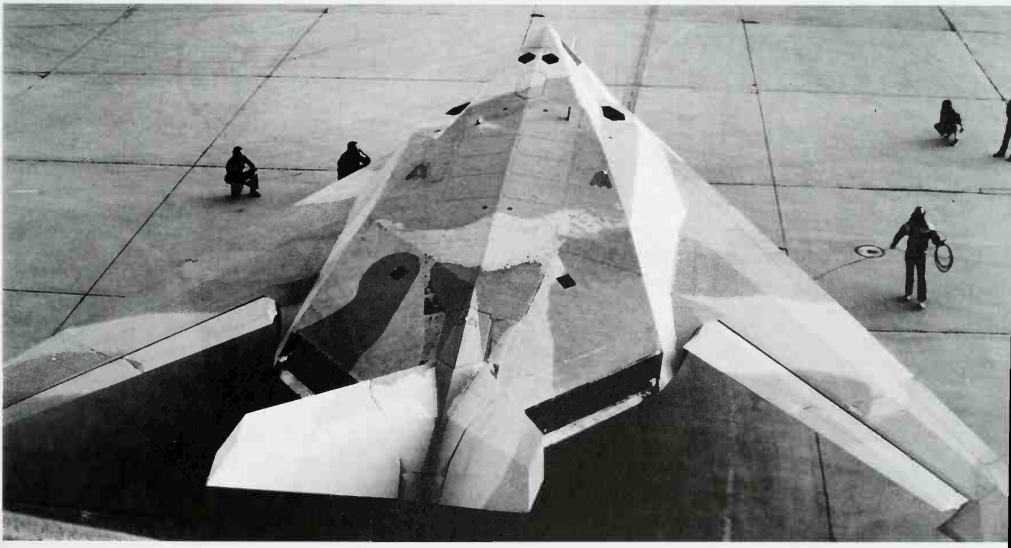
from the Ames Research Centre being made available on 16 August, that same year.

To achieve the required range, while remaining within other stated parameters, it became necessary to reduce the proposed payload of ATA 'B' to 7,500 lb (3402 kg). As assimilation of the two proposals continued, it became increasingly apparent that ATA 'B' (despite being strongly favoured by Strategic Air Command, following cancellation by the Carter administration of the B-1A), was in the upper right corner of what was at that time considered realistically achievable. Consequently, in the summer of 1978, Air Force officials decided to terminate further studies involving ATA 'B' and instead opted to move forward with ATA 'A' into full-scale development (FSD).

Covert funds were established, and key individuals serving on the House Appropriations Committee (HAC), the House Armed Services Committee (HASC), the Senate Appropriations Committee (SAC) and the Senate Armed Services Committee (SASC) were briefed on the programme. On 1 November 1978 production was authorised, the

Right: On arrival from Burbank, FSD 1 is seen here supported by hydraulic jacks in a hangar at Area 51, while undergoing final assembly. Note the wing attachment points at the root. *(Lockheed Martin)*

Below: Note the two blow-in doors cut into the aircraft's upper intake ducts to increase airflow to the engines at low operating speeds. These caused Hal Farley some consternation when they 'modulated' half a dozen times during his first flight, generating loud 'thumps'. *(Lockheed Martin)*



Senior Trend chief test pilot Hal Farley, completed '780's first flight on 18 June 1981. *(Lockheed Martin)*

programme was accorded the code-name *Senior Trend* and Lockheed was awarded a $340-million contract to cover the cost of building five FSD aircraft, plus providing spares, support and flight testing (this amount did not include the cost of purchasing the aircraft's General Electric engines).

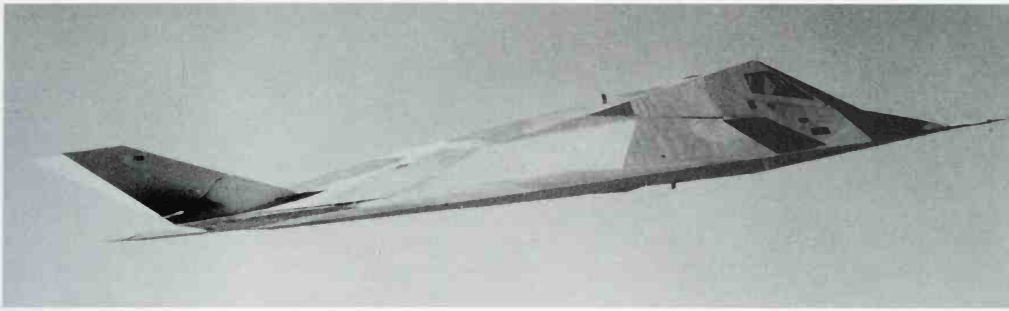
Development of *Senior Trend* and other low observable programmes was transferred from the SPO commanded by Col Dave Williams at the Pentagon, to a newly established SPO under Aeronautical Systems Division, located at Wright-Patterson AFB, Ohio. Known initially as the Classified Aeronautical Systems Programme Office (later re-designated as the Directorate of Low Observables), its first director was Col David B. Englund; Jerry Baber also transferred from the Pentagon and Col Eldred D. (Don) Merkl, became the Air Force's first *Senior Trend* programme manager.

The production timescales for this revolutionary aircraft programme were tight; its first flight was planned for July 1980 – hence the last three digits of the prototype's serial number were 780 (its full serial was 79-10780) – and initial operational capability (IOC) was to be achieved in March 1982 and the planned production run was 20 aircraft.

On 1 January 1979, construction of a full-scale wooden mock-up began. Eleven months later, on 3 December, the assembly was completed, and functional engineers then used this representation to determine where to situate various aircraft subsystems (such activities have now been superseded by advances in computer software). Construction of FSD 1, the prototype F-117A (Aircraft '780), commenced at Burbank in November 1979.

The task

The F-117A Nighthawk is a survivable interdictor; the determinant in achieving this role successfully has been the development of VLO techniques. To confound the principle detection medium – radar – design focused upon producing a low RCS. Previous development work had largely been focused around producing materials capable of absorbing incident radiation. The characteristics of this radar-absorbent, or radar-attenuating, material (RAM), addressed three areas of signal attenuation but, until the *Have Blue* programme, little was understood about shaping as a means of reducing RCS, beyond utilising a blended body, fuselage chines, together with tail units canted inboard, to facilitate low side-look signatures. The use of RAM certainly achieved a reduction in RCS values, but by no means enough to gain 'an explicit operational advantage'; that could only be achieved when designers were able to build a shape both capable of performing an operational mission and producing an RCS lower by several orders of magnitude than any current conventional aircraft. It was here that the odds were definitely stacked against the designers, as perfectly



Above: Only three pilots were to fly '780 in its 'Desert' scheme, prior to the aircraft being stood down after its tenth flight. The second pilot was Skip Anderson, who was also the first Air Force pilot to fly an F-117.

Top: Aircraft '780 undertakes an early test sortie. *(both Lockheed Martin)*

demonstrated by the radar equation which basically states that: 'detection range is proportional to the fourth root of the radar cross-section'. That is to say, in order to reduce the detection range by a factor of ten in number, it is necessary to reduce the target aircraft's RCS by a factor of 10,000.

Having established an overall shape that meets the stated RCS criteria, it then becomes necessary to consider other aspects of an aircraft's design that will impact on these values. In the case of a conventional jet aircraft, careful consideration is given to the air-intake and exhaust cavities, for as in the case of an inlet, radar energy will travel down this and be reflected back from the engine compressor face, rather like the beam from a lighthouse – predominantly, straight back to its source. The F-117A's inlet is positioned above the wing and the inlet duct curves very slightly down to the compressor, thereby providing it with an element of shielding. Further reductions in RCS values are achieved by placing a grid over the inlet. The spacing of these grids is just 1.5 cm (0.6 in), and the top of the intake is angled back from the lower edge with a further nose-aft sweep applied, to reflect radar energy away from the nose-on aspect. RAM is also applied to the

Aircraft '780 underwent its first series of updates from 6 August 1981 to 21 October 1981, during which time larger fins were fitted to improve directional stability and the earlier 'Desert' paint scheme was replaced with an overall, low-visibility grey scheme. *(Lockheed Martin)*

grid so that the entire unit functions as a shock absorber and any remaining energy that has not been reflected away from the unit, is absorbed by a further coating of RAM inside the duct.

'French fry' problems

Ice encrustation was never an issue with *Have Blue*, as it was purely a research aircraft and could therefore be flown in a selective manner. The F-117A, however, is an all-weather aircraft and icing was a major issue. Extensive tests conducted very early in the programme determined where icing was liable to be a problem. In addition to the air data system, the other area identified was the inlet grids. Initial testing showed that if any ice build-up remained restricted to within the grid holes, then differential pressure would drive the pieces of ice into the engine like French fries, and the engine could digest them without damage. The problem became difficult if the ice bridged across the front grids, thus significantly slowing flow to the engines. Several approaches were examined, one possible solution featured putting electricity-conducting wires along the leading edges of the grid, much like a rear window defogger in a motorcar. However, despite trying different sizes of system and different materials, the team was unable to avoid an unacceptable increase in radar cross-section. Finally, an old-fashioned windscreen wiper blade was developed which, when not operating, tucked away inside a box below the inlet without increasing the radar cross-section.

In operation it covers about 80 per cent of the inlet area, and keeps the ice in the 'French fry' category, so that it can be easily digested.

An aircraft's cockpit is a major source of unwanted signal return generators. To prevent radar energy reflecting back from numerous corner reflectors – not to mention the pilot's head – which in itself has a larger RCS than the entire aircraft, the F-117A's cockpit windows are metallised. They work much like metallised sunglasses; thus allowing the pilot to see out, but to all other intents, performing as a faceted panel in relation to electromagnetic radiation; reflecting energy away from its source.

For target acquisition, the F-117A has a system known as the Infra-red Acquisition and Designation System (IRADS). Unique to *Senior Trend*, the system's hardware consists of two external elements; a unit mounted in the upper nose section, known as the FLIR and a downward-looking infra-red (DLIR) unit, located in the underside of the aircraft's nose section. Completely self-contained, the system enables the pilot to perform night-time recognition and designation of his targets for guided weapons, without recourse to the telltale, electromagnetic radiation emissions associated with radar. Mounted in turrets, which in turn are located in commodious cavities, these sighting units required apertures that were able to pass infra-red and laser energy out and back, but be opaque to radar. Originally developed as an interim solution, a high tensile, fine wire screen was designed that satisfied these requirements. Tests were also conducted to ensure that the inside of the cavities did not succumb to sonic fatigue, as they were to a degree exposed to airflow; however, they performed admirably and were only replaced by newly designed units from 13 April 1994.

Other problems

Other early problems related to the maintainability of the aircraft's RAM, as Alan Brown, a senior design engineer recalls: 'The trailing edge of the exhaust nozzle was comprised of multiple ceramic bricks which were loaded with radar-absorbing material. These in turn had to be attached by their leading edges to a high temperature structural member and on their lower edges to a lower temperature radar-absorbing, non-metallic, structural member. The combined requirements of structural rigidity, low cross-section and compatible thermal expansions, made this an extremely difficult design issue. Maintainability was also an extremely important feature, and a substantial part of the flight test program was devoted to steady improvements in all these areas. The internal shell of the nozzle itself was coated with a radar-absorbing material that had to be effective in its prime purpose, remain adhered in a heavily fatigue-inducing environment and be compatible in thermal expansion, with the basic nozzle structural material. Well into the production programme, we were still removing nozzles for recoating every 400 hours.

'The coating applied over the rest of the aircraft was originally made up of 8 ft by 2 ft [2.44 m by 0.61 m] sheets glued on to the aircraft's surface like linoleum tiles. When I watched the first aircraft being coated and saw the number of people involved, I made a quick calculation and realised that it would cost $750,000 just in labour to apply the material [to each aircraft]. We also found that it was very difficult to come up with an adhesive that was impervious to all fluids that an aircraft carries. In particular, hydraulic oil was very pervasive. Fluid would leak inside the aircraft, drip through the aircraft skin, dissolve the adhesive and drop out of the airplane maybe 6 ft [1.83 m] away from where the original leak started. You can imagine the frustration of chasing down leaks of that type.

'All this led to a crash program to come up with a spray coating that was environmentally safe, satisfactorily bonded and preserved the required radar attenuation characteristics. We eventually installed what became the largest computer-controlled system in the country, if

not the world. When you think of the faceted shape of the F-117A and imagine having to spray-paint around the corners while preserving the required thickness, you realise that the computer programming was not trivial. The machine had to be able to 'walk round' a complete aircraft, applying multiple coats (the final thickness was much greater than conventional paint) and finish with a structurally sound, low-maintenance coating with absolutely the correct radar-absorbing characteristics at all points on the vehicle.'

Other considerations

In addition to producing a low RCS, the F-117A designers also paid good attention to reducing electromagnetic emissions and infra-red radiation from the aircraft's hot parts. An important feature of low-observability design is that, in general, the differing observable disciplines are mutually inclusive and that if something is good for reducing radar returns, it is often found to be good for reducing infra-red returns and vice versa. It was appropriate to shield the exhaust nozzle for both radar and infra-red reasons. The high aspect-ratio nozzle design was selected to minimise these returns and also had the effect of increasing the surface area of the exhaust wake, which rapidly increased its cooling (good for both radar and infra-red). This also increased the acoustic frequencies, thus attenuating sound to a far greater extent than if exhausted through a conventional, circular nozzle. One area of partial conflict was the platypus-bill shaped shield behind the exhaust nozzle. This reduced direct radar reflections and infra-red emissions from the exhaust nozzle at the expense of generating some infra-red radiation from the shield itself. However, because the vast majority of detectors and anti-aircraft weapons would threaten from below the aircraft, it was elected to allow this radiation to be seen from above.

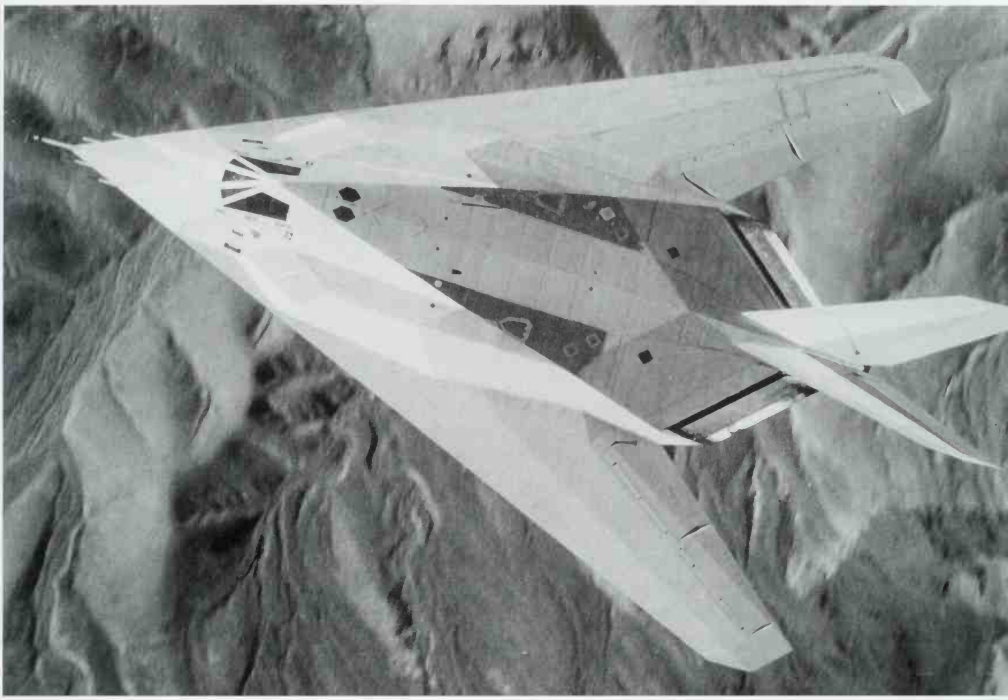
An operational threat analysis was conducted, modelled on data and assumptions commensurate with a NATO/Soviet/WarPac conflagration. Range specifications dictated basing the aircraft in-theatre, the fall-out from which identified the principal radar types to be deceived in order to significantly enhance survivability. These were airborne intercept and SAM radars, which typically operate on a wavelength of between 3 and 10 cm.

Working on the premise that all the RCS goals had been met, the aircraft would now be 'blind' to detection by attack radars. The next phase of the operational analysis considered optimum speed and altitude in order to achieve accurate weapon delivery. It was soon determined that flying at supersonic speed did not enhance survivability. Indeed, flying at high subsonic speeds actually increased survivability by reducing a defender's ability of detecting the aircraft using infra-red systems; therefore it was decided that the platform would be powered by non-afterburning engines, which also reduced airframe temperatures, further lowering its IR signature.

Stealth advantages

Flying at tree-top height and 500 kt (927 km/h; 576 mph) does not leave much time to acquire the target, it also places the attacking aircraft within range of many more weapons systems. At the other extreme; maintaining a similar KEAS (knots equivalent airspeed) at 10668 m (35,000 ft), provides the aircraft with greater target acquisition time, but to be effective weapon dispersal has to be much greater. Optimum weapon effectiveness was achieved by placing the aircraft at medium altitude, which, for a subsonic aircraft, touting a modest performance envelope, would be utter suicide – but for stealth.

The amount of stealth required to enhance survivability depends upon the 'detection zone'. Therefore, with the aircraft maintaining high subsonic speeds, a successful missile attack from the flank would require the weapon to undertake a tight high-g turn, a manoeuvre still outside the envelope of most systems. From the rear, hopefully the aircraft would have already hit its target and be returning home, thereby



Above: Alan Brown, *Senior Trend's* programme manager and low-observability guru, scientifically proved that grey was the best LO paint scheme for the aircraft. However, Gen. Screech, Commander of Tactical Air Command, decreed that the 1-17s should be painted black.

Between 4 January and 3 February 1984, Aircraft '780 had wing leading edge extensions added to improve its handling qualities. *(both Lockheed Martin)*

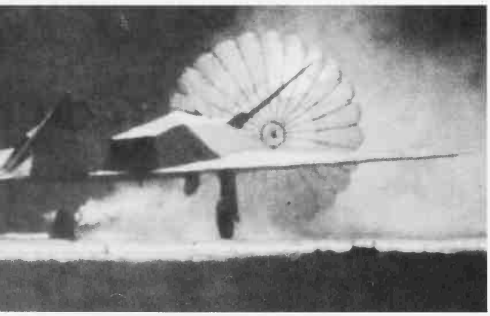
placing the missile in a catch-up situation. Directly above and below the aircraft are zones of almost negligible importance. However, the aspect that presents the defender with the greatest chance of a successful intercept is the frontal zone. If the threshold of detection, by radars using wavelengths of between 3–10 cm, can be foiled to a point where the aircraft is just one minute flying time (about 16 km/10 miles),

from the radar head, then there is a good chance of avoiding a successful intercept. Therefore, by pulling all these strands together, we can see that an F-117A, flying at an altitude of 3658 m (12,000 ft) and 500 kt, will achieve that one minute detection goal parameter by being at its most stealthy from a head-on aspect, and at 25° look down, and 25° look up angles.

Flight testing

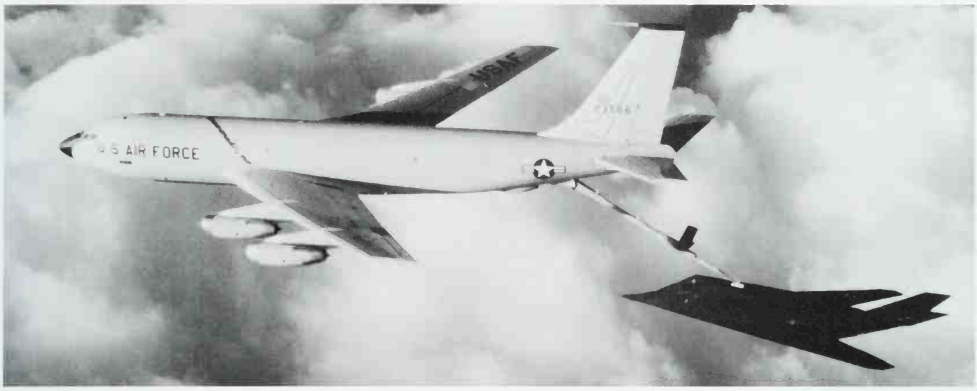
Following recovery from his near-fatal accident in the *Have Blue* prototype, Lockheed's chief pilot, Bill Park began recruiting the initial cadre of company test pilots into the *Senior Trend* programme. The first to be poached was Hal Farley, who became the chief project pilot; at the time, Farley was working for Grumman flying F-14 Tomcats from Naval Air Station Point Mugu. Next came Dave Ferguson, who was on his final Air Force tour as commander of the 'Red Hats', a covert unit flying Soviet aircraft at Area 51 as part of the 6513th Test Squadron. He had checked Park out in a T-38 up at Area 51, prior to Bill flying *Have Blue*. Then came another ex-Navy pilot, Tom Morgenfeld; his background was on the McDonnell Douglas YF-18 project development team.

In addition to contractor pilots, it had been decided that developmental, together with Category I and II operational test and evaluation (OT&E) of the F-117A, would be conducted by a joint test force. Tactical Air Command (TAC) controlled testing and initially provided three pilots and two analysts. These numbers grew as preparations for the first operational squadron got underway. The third party involved in this 'tripartite' force was Air Force Systems Command (AFSC), which provided three pilots, four engineers, and approximately 40 aircraft maintenance personnel. The unit, based at Area 51, was designated Detachment 5 (Det 5) and headed up by Lt-Col Skip Anderson, who reported in parallel to both Col Pete Winters, commander of the Air Force Flight Test Centre (AFFTC) at Edwards AFB and Col Don Merkl, programme manager at the SPO.



This heavily enhanced shot, taken from a video camera, shows Tom Morgenfeld recovering Aircraft '782 onto a bed of foam at Area 51 on 27 January 1982, following loss of the nose wheel. *(Lockheed Martin)*

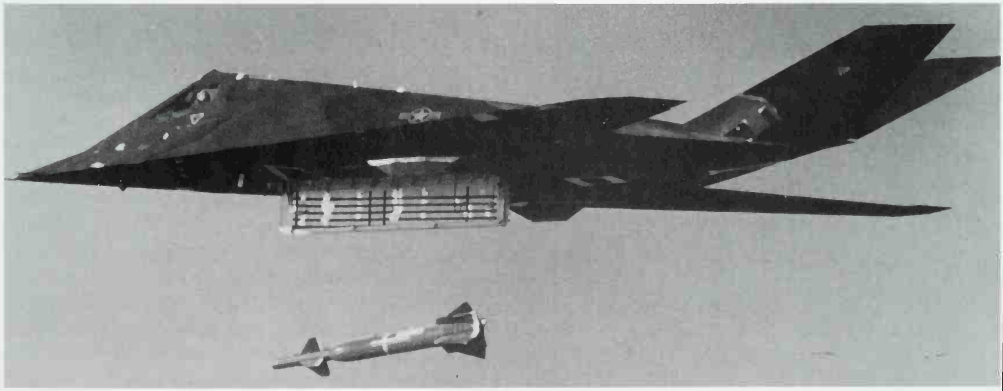
To prepare themselves for the first series of flights in the F-117A, Skip Anderson recalls: 'We spent a lot of time with Bob Loschke in the Lockheed simulator out at Rye Canyon, working the control problems. The key effort became one of finding a set of gains that supported both up-and-away flight and an engine failure on take-off. I recall we ran the sim off the runway a discouraging number of times. We also flew F-16s on a few occasions because it too was a fly-by-wire system, plus we practised the F-117's early flight profiles in F-4s and T-38s. In my opinion, the F-16 was of little value to our preparation because of the side stick, and in the event Bob's simulator turned out to be quite accurate.' In addition, the team contracted Calspan to provide a flight simulation that was based upon aerodynamic data acquired through wind tunnel tests and the *Have Blue* programme. However, owing to the highly classified nature of *Senior Trend*, the data was delivered to Rogers Smith of Calspan by Farley, Ferguson, Morgenfeld, and Bob Loschke in a restaurant out at Newhall. During that meeting they discussed what they wanted from Calspan; however Rogers could not be told what he would be simulating. All he was given to work from was a set of aerodynamic data.



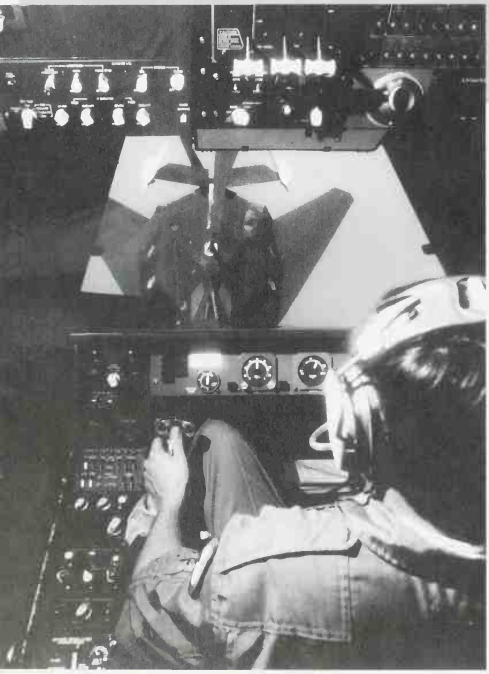
At 07:07 on 17 November 1981, Lt-Col Skip Anderson was airborne in '780. During the course of the 2 hour 12 minute flight he successfully completed the first F-117 air refuelling contact, with a KC-135. *(Lockheed Martin)*

Some months later, Farley got a call from Rogers informing him that the simulation was ready. He, together with Dave Ferguson and Major Russ Eastor then flew up to Buffalo. Farley recalls: 'I'm not sure whether Russ flew the NT-33 [a modified Lockheed T-33 trainer] or not, but Dave and I took turns. I think we flew it three times apiece, varying the stability in pitch and yaw and performing take-offs and landings and degrading the flight characteristics below the air data we had, in order to see if we could land it. It turned out to be a valuable learning process for us; the airplane was flyable in its degraded state and this gave us some confidence that even if the air data was wrong, we would be able to get it back on the ground safely.'

In keeping with the earlier *Have Blue*



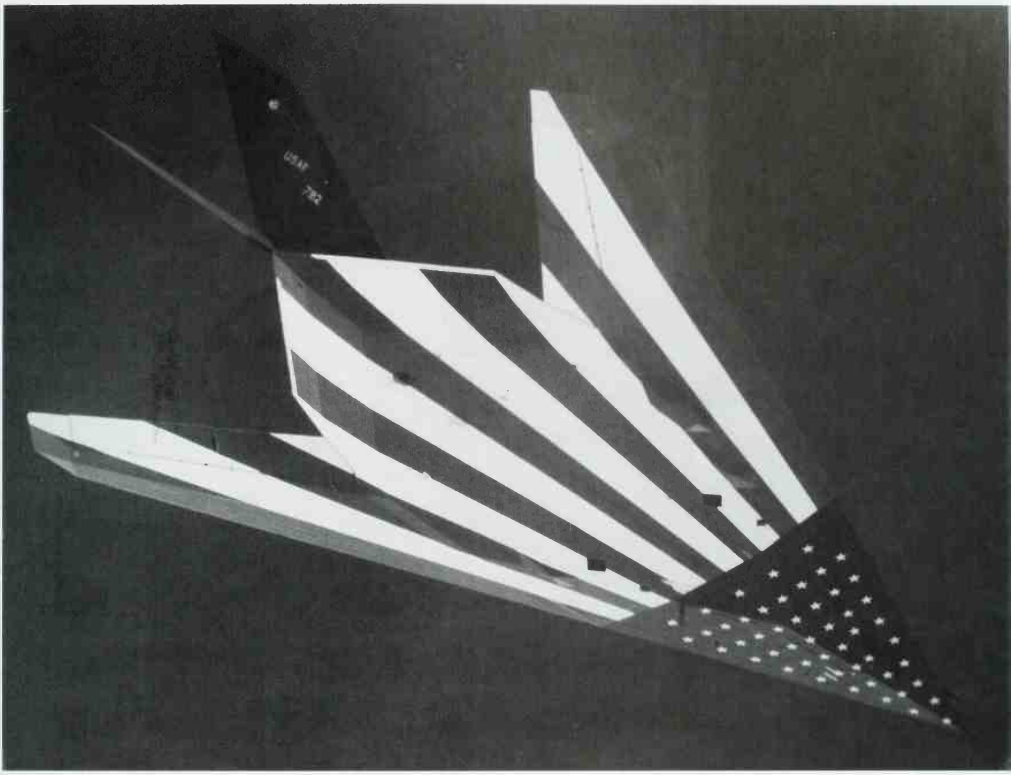
Aircraft '784, the final FSD aircraft, is seen here dropping a 2,000-lb (907-kg) GBU-27 LGB during trials. Note the unusual under-wing fairing and the smaller structure under the nose, both housing cameras to record weapon separation characteristics. *(Lockheed Martin)*



Another milestone was reached on 6, 7 and 8 September 1983, when Dave Ferguson carried out three flights in '781 to qualify the aircraft for tanking with the KC-10. *(both Lockheed Martin)*

programme, flight testing would be conducted at Area 51. On 1 January 1979, preparations at the remote site got underway in readiness to receive its latest guest. On 16 January 1981 a C-5 from Burbank touched down at Groom Lake, onboard was Aircraft '780, FSD 1 – the combined test team at last had an aircraft.

At 06:05 on 18 June 1981, BANDIT 01 began its take-off roll, getting airborne a few knots earlier than target speed. Soon afterwards the aircraft began a slight yaw to the right, Farley countered with opposite rudder, but after a sluggish response, the aircraft yawed slightly more this time to the left; more restorative rudder induced yet another yaw isolation in the opposite direction coupled with increasing side-slip. Unhappy with how things were developing,



When the flight test detachment changed command from Roger Moseley to Paul Tackabury on 14 December 1983, John Beesley completed a memorable fly-by in '782. *(US Air Force)*

Farley switched on the yaw access mode of the autopilot, and immediately the aircraft stiffened up. As the flight progressed Farley got a canopy warning light, but after a short discussion with the ground station it was decided that the micro switch had activated after slight canopy movement. The flight continued, but then a temperature build up in the exhaust section caused Dick Burton, on the ground, to call for an abort. On the way back to home plate, Farley made some very small, abrupt, control inputs in pitch, yaw and roll; known as MMLE (modified maximum likelihood estimator) inputs, they were part of the planned profile that enabled aerodynamicists to see how the aircraft actually responded to the predicted aerodynamic coefficients. Aircraft '780 landed about 15 minutes after take-off.

After its first ten flights, the first six of which were flown by Farley, '780 was laid-up for four months, during which time various modifications were made, including the installation of a partial heat-shield to the rear underside of the fuselage and the fitting of larger tailfins to improve directional stability. Upon returning to work in October 1981, '780 was air-

When Ben Rich retired from the Skunk Works, 85-0831 was on hand to mark the occasion appropriately. *(US Air Force)*

refuel qualified by Skip Anderson on 17 November; that action accelerated the test programme by increasing flight duration time.

As flight handling and envelope expansion tests continued on the prototype, FSD 2, Serial 79-10781, carried out a series of initial airborne RCS tests. These involved the application of sheets of BX210 RAM and the flight tests, conducted by Major Roger Moseley, proved extremely encouraging. On 11 June 1986, Aircraft 85-0818 became the first F-117 to have a radar absorbent coat of BX199 applied robotically; four years later another programme was initiated to further improve the material's durability and maintainability and by mid-1993, a substance designated BX185 had been successfully developed and work then began on upgrading the rest of the fleet.

FSD aircraft Number Three 79-10782 was the dedicated avionics testbed; while '783 was earmarked for exhaustive low-observability testing, the first of which began against a Boeing NKC-135 Stratotanker on 15 July 1982, to ascertain the aircraft's IR signature; these tests continued against a McDonnell Douglas F-4 Phantom II, before broadening out to include

RCS testing both cued and uncued, against ground and airborne threats.

Paul Tackabury notched up another milestone in the aircraft's development on 17 December 1982, when, during the course of a 1 hour 24 minute test sortie in Aircraft '782, he successfully completed the first weapons release from a 1-17, when he dropped a Mk 106 practice bomb from a BDU-33 canister while in level flight.

Aircraft '783 continued to be the fleet's RCS workhorse throughout 1984, with analysis of the air-to-air threat continuing. On 24 April 1984, an F-16 made four radar passes against the aircraft while it was being piloted by Morgenfeld. Two days later, the same aircraft saw an F-16 make thirteen passes against it and by 23 July, F-15s, F-14s and a Grumman EF-111 Raven had conducted similar threat tests. Thereafter, '783 was used alternately between low-observability tests and the integration and evaluation of improvements made to the navigation and weapons delivery systems.

FSD 5, Aircraft 79-10784, was the dedicated IRADS testbed and its first 106 flights were conducted in association with achieving the successful integration and operation of this unique weapons delivery system. It was subsequently placed in temporary storage on

F-117 depot maintenance is conducted at Air Force Plant 42, Site 7, Palmdale. Also located at Site 7 is the 410th Flight Test Squadron. *(Lockheed Martin)*

completion of a sortie flown by Roger Moseley on 23 September 1983, however, and at the end of November 1984, the aircraft was dismantled and flown back to Burbank in a C-5. The operational shortcomings of a visual targeting system had long been appreciated, and when '784 next flew from Area 51 on 4 September 1985, it was equipped with a low-observable radar system. On completing its final flight in this configuration on 12 December, every aspect of the system had been evaluated in 34 sorties – the RCS of the antenna and radome, its ability to perform the ground-mapping task and threat evaluation during system operation. Those interviewed who were involved in the programme have remarked that the system was incredibly stealthy, however it was not deployed on the fleet for reasons of cost and on the basis that stealth, as a concept, had yet to prove itself operationally.

The 1-17's fuel system was originally designed to retain fuel in the wings for as long as possible. This was thought to significantly lower in-flight loads, as the aircraft's centre-of-gravity (cg), was positioned further aft, thereby leading to extended airframe life. But as flight testing progressed it was determined that elevon control power was less than predicted, with the aircraft becoming increasingly more difficult to manage at higher AoA when configured with high aft cg settings. To regain this loss of control power, FSD 1 was grounded between 21 December 1983 and 4 January 1984, during which time wing leading edge extensions were added. During nine subsequent flights in this configuration the modification was judged to have achieved its

Aircraft 85-0831 completed 17 flights with the operational fleet before being transferred to flight test duties. It undertook its first flight with its new 'owners' on 1 December 1988. *(Paul F. Crickmore)*

stated objectives; however, the Air Force again decided not to modify the exterior of production aircraft. Instead, fuel sequencing was changed, and wing fuel was used first, thereby avoiding degraded elevon control suffered during high alpha (AoA) manoeuvres and aft-cg conditions. Subsequently, the structural engineers decided that in any event, flying the aircraft in aft-cg conditions made little difference by way of increased airframe life.

Functional check flights

An additional responsibility carried out by Lockheed test pilots, was to complete all functional check flights (FCFs) for each 1-17 as it arrived at Area 51, prior to being commissioned by the Air Force. The first production aircraft due to be received in this way was Aircraft 79-10785 (or possibly -0785); like all 1-17s, it was airlifted to the test area via C-5 Galaxy, re-assembled and then subjected to various ground checks before, on 20 April 1982, company test pilot, Bob Riedenauer advanced the throttles to take the aircraft on its first flight. Aircraft '785 rotated as planned, but immediately after lift-off everything went horribly wrong. The nose yawed violently, it then pitched up, and completed a snap roll that left it on its back before impacting the ground. It was nothing short of a miracle that Riedenauer survived; but the 1-17 was totally wrecked. A post accident investigation established that the pitch and yaw rate gyro inputs to the flight control computer had been cross-wired. The result was that as the aircraft rotated, the computer's interpretation of events was that of an uncommanded yaw departure. Its 'restorative' action therefore was to apply rudder. This caused a real yaw departure, which the computer perceived as a movement in pitch. A full-up elevons response was therefore communicated to the flight control surfaces, resulting in what so easily could have been a fatal accident. Riedenauer suffered two broken legs and other injuries that ended his test pilot career. A production, performance and quality audit was initiated by Lockheed, after which the gyro connectors were redesigned to physically prevent misinstallation.

Squadron Leader Dave Southwood (pictured) and his boss, Wing Commander Colin Cruickshanks, each flew the F-117 on five evaluation sorties during a unique series of trials in May 1986. *(Crown Copyright)*

Interest in this revolutionary aircraft was also expressed by the US Navy and during the latter part of October 1984, Lt Cmds Kenny Linn and Ken Grubbs flew '783 and '782 for a total of 11 hours 24 minutes, evaluating the 1-17 for carrier operations. Afterwards, Linn commented: 'Unremarkably, it wasn't suitable at that time for CV use, although it had quite nice handling characteristics in the pattern, landing speeds were too high and the sink rate limitations were too low. The F-117A had not been built as a CV aircraft and it was not going to turn into one overnight.'

Also in 1984, work began on improving the aircraft's avionics architecture by increasing onboard computational power. Under what was

known as the Offensive Capability Improvement Programme (OCIP), two aircraft, '782 and '784 had their Delco M326F computers and interconnecting databus removed and replaced with three IBM AP-102 MIL-STD-1750A units and a unique high-speed databus. This Weapons System Computational System (WSCS) upgrade was supplemented on '784 with a Weapons Bay Improvement (WBI) upgrade; for the first time this enabled the 1-17 to perform dual-bay weapon deliveries and drop the GBU-27 laser-guided bomb (LGB). To achieve this, test instrumentation was removed from the bomb bay into a modified fuel tank area – the modifications required 11 months to complete. Subsequently, for two years, from 22 July 1987, '784 chalked-up nearly 200 flights attributed to weapons evaluations and delivery profiles.

Not all flights progressed seamlessly through the test card however, as Major John Beesley discovered early on the afternoon of 25 September 1985. Shortly into the sortie, and following a pull-up manoeuvre at 3048 m (10,000 ft), the left fin completely failed. The incident, which was filmed from a chase plane, ended without further incident, as Beesley retained control of the aircraft and completed a successful recovery back at Area 51. Having saved a highly valuable aircraft, and in so doing demonstrating outstanding pilot skill, Beesley was secretly awarded a Distinguished Flying Cross.

Lead IRRCA test pilot is Jim 'JB' Brown. *(Paul F. Crickmore)*

British evaluation

Following the combined USAF/US Navy raid on Libya in April 1986, the RAF had its chance to evaluate the 1-17 by way of a thank you from President Reagan to the Thatcher administration for allowing UK bases to be used as launching points for the attack. Accordingly, in early May, two RAF test pilots from Boscombe Down, Wing Commander Colin Cruickshanks and Squadron Leader Dave Southwood, deployed in civilian clothes and under conditions of great secrecy to Nevada. Hosted by one of the 'operational squadrons', the 4452nd Test Squadron (TS), each pilot accrued about six hours on type before returning to the UK and compiling a highly classified debriefing disk that remained secured in a Boscombe safe for several years before eventually being cleared for destruction.

After '780 was retired, the test fleet was again boosted to five, when in February 1988, 85-0831 joined its ranks, having completed 16 flights with the operational wing. Following much re-working, this aircraft became the testbed for Phase 2 of the OCIP, which incorporated updates to improve pilot situational awareness and reduce workload.

Since the conceptual *Have Blue* programme, Area 51 had served as host for low-observability flight test operations from November 1977, but as elements of stealth ventured out from the 'black world', it became possible to move the operation to a more amiable site. So it was that on 27 March 1992, Det 5 moved to Palmdale and became the 410th Flight Test Squadron (FTS), with the first *Senior Trend* test sortie (a weapons evaluation test), being flown from the base by Jim Thomas in Aircraft '784 on 23 April 1992.

With engines turning (note the open upper intake ducts), pre-taxi checks are worked through. Also note the two extended SUU-20 practice bomb and rocket dispensers extending from the two open weapons bays. *(Paul F. Crickmore)*

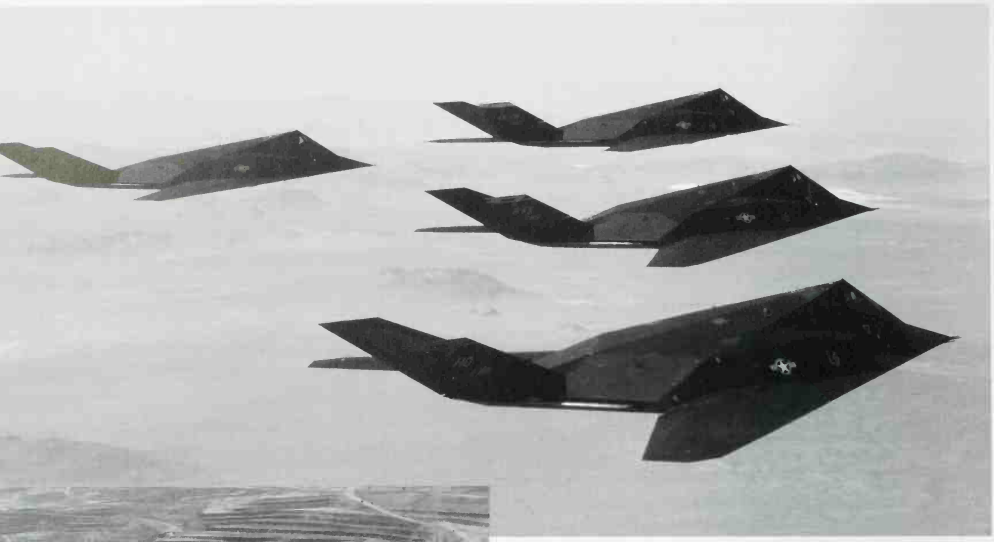
Further trials

At this stage of its career, once a Nighthawk was 'stealthed-up' during an operational sortie – with its antennas retracted and the like – further communication was impossible until the aircraft had completed its mission, arrived back at a pre-arranged contact point and once again extended its antennas. On 23 October 1991, a low-observability communications study was authorised to identify methods of overcoming such problems. The result was the development of a stealthy antenna that was evaluated between 31 August and 13 November 1992 on Aircraft '783. The system received full-scale development go-ahead on 12 May 1993 and work to upgrade the fleet began just four months latter.

However, not all programmes meet with the same level of success; for example, it is believed that *Senior Shade II* involved 14 flights between 12 July and 22 September 1993, aimed at reducing the aircraft's visual signature. For this, aircraft '782 was painted light grey, it flew in company with another 410th aircraft – usually '831 – enabling direct comparisons to be made between the effectiveness of the paint scheme; that 1-17s are still black probably indicates the evaluations findings!

Yet another attempt to reduce the chances of visual acquisition took place over four flights, between 19 and 22 July 1993. Under the code-name *Senior Spud*, Aircraft '784 was half-covered in a textured, reflective surface – the same comments as above apply!

OCIP Phase 3 commenced on 10 October 1994 and it involved replacement of the aging SPN-GEANS inertial navigation system (INS), with a new Honeywell H-423/E Ring Laser Gyro (RLG). The original acronym for this element of the programme was to have been RNIP (Ring Laser Gyro Navigation Improvement Program), however the addition of a Rockwell-Collins global positioning system (GPS), gave rise to the title RNIP+. To accommodate the GPS antenna a 'dry bay' was created by forming a recess in the fuselage fuel tank on the upper surface of Aircraft '784, into which was located a stealthy antenna capable of receiving the relevant satellite-generated data. The first RNIP+ flight occurred on 12 December 1994 and its advantages were immediately apparent. Consequently this improvement package was incorporated on the entire fleet. Further development of this technology got underway in December 1997 with a flight test project known as Integrated Real-time Information in the Cockpit/Real-time Information Out of the Cockpit (IRRCA). By 30 June 1998 the first phase of the programme, 'real-time information into the cockpit', had been successfully demonstrated. At the heart of IRRCA is the integration of a real-time symmetric multi-processor facilitating 1.2 billion instructions per second. As the 1-17 receives threat updates from satellite broadcasts, a moving map displays new threats and the processor automatically evaluates the situation. Should analysis of the threat determine that the aircraft is in peril, the processor re-plans the route and displays the option on a new colour liquid crystal diode multi-function display. Decision criteria used in



To celebrate 20 years since the F-117 first took to the air, two four-ship elements, plus a single four-ship formation of AT-38s (left) participated in a fly-by at Edwards AFB. *(both Lockheed Martin)*

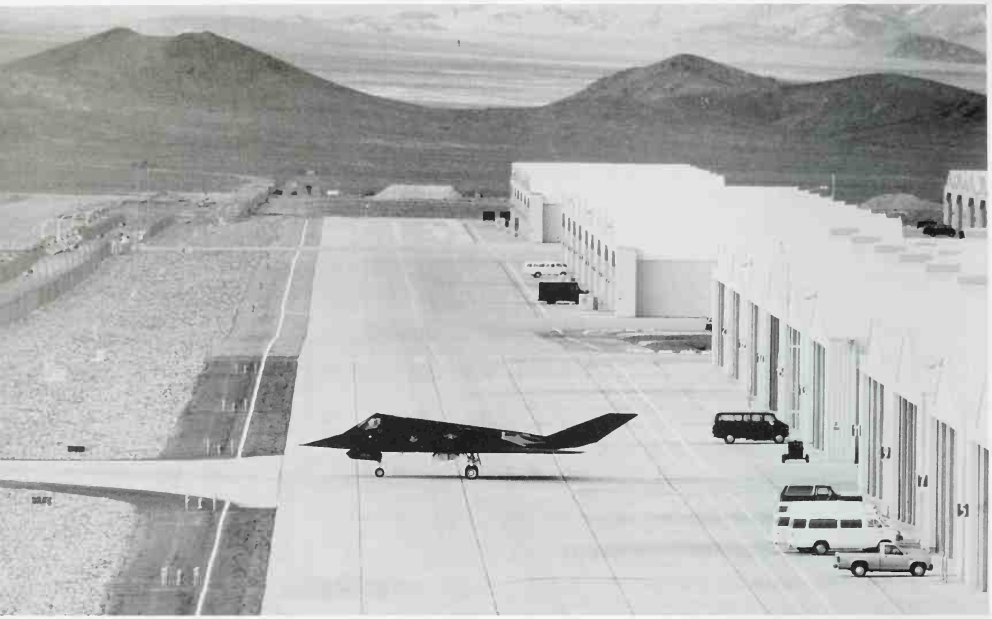
the proposed re-route includes threat exposure, flying time and landing fuel. The pilot can then accept or reject the proposed option. In addition to mission information, text and images also update the pilot on key events and weather. Evaluations carried out by the 410th indicate that the 1-17 is capable of reacting to mission updates or target changes and pop-up threats, while still remaining in a stealth configuration. On 30 June 1998, Jim 'JB' Brown, lead IRRCA test pilot, flew a 1 hour 12 minute simulated combat mission in the dedicated testbed, Aircraft '784. During the course of the sortie a satellite in geosynchronous orbit transmitted a series of encrypted messages to the aircraft via its low-observable communications antenna. These messages included threat updates, mission updates, text information and alternative target imagery.

Mission changes provided information for the real-time symmetric multiprocessor to re-plan the mission to an alternative target. This was followed by a text message and photos of the alternative target, which enabled Brown to verify the processors planning results and study target details prior to acquisition and attack. Phase Two of the project, 'real-time information out of the cockpit,' reached laboratory demonstration capability in June 2001, however, there appear to be no funds currently available to deploy this piece of technology on the 1-17. Time-critical targeting appears to be destined for other aircraft in the Air Force inventory – 'No Bucks, no Buck Rogers!'

3. Operational History: The Tonopah Years

Formed on 15 October 1979, and designated as the 4450th Tactical Group, and referred to as A-Unit, the Air Force's first operational F-117 unit was commanded by Col Robert 'Burner' Jackson. To preserve security, the unit reported directly to the Tactical Air Command (TAC) director of operations (DO), instead of a numbered Air Force. Whilst work on aircraft Number One '780, continued at Burbank, Bob Jackson began organising a new covert operational base which, it had been decided, would be the Tonopah Test Range, located north-west of Nellis AFB, Nevada. To bring the site up to scratch, a three-phase, multi-million dollar construction programme was launched. Phase One consisted of little more than peripheral work, which included the construction of 16 large mobile homes, however, Phases Two and Three completely transformed the base; the original 6,000-ft (1829-m) runway, built in 1954, was increased to 12,000 ft (3658 m). Maintenance facilities, a control tower, fuel and weapon storage areas, as well as permanent housing, were also built, together with individual aircraft hangars that were organised into parallel blocks and referred to as canyons. By early July 1982 the enormous construction programme was complete. Twenty Ling Temco Vought A-7s – mostly single-seat A-7Ds, but including a small number of two-seat A-7Ks – provided a cover story for the unit. These aircraft were based at Nellis AFB and referred to as P-Unit. Other support elements of the 4450th were given similar oblique and short nicknames, to further conceal their purpose; the 1880th Communications Squadron became C-Unit; Det 8 of the 25th Air Weather Squadron was D-Unit, and the 4450th Combat Support Group E-Unit. The 4450th Test Squadron (established on 11 June 1981), was I-Unit and Det 1 of A-Unit, based at Tonopah, was Q-Unit. In addition to providing the 'avionics testing', cover story, the

LTV A-7s provided both a cover story and a proficiency platform for pilots of the 4450th Tactical Group. *(US Air Force)*



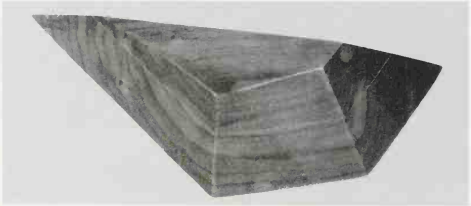
The barns of Tonopah were 'drive in–drive out' and grouped in blocks of six. Note the odd numbers by each hangar door and the sparse 'tumbleweed and tarantula world', that existed beyond the perimeter fence. *(Lockheed Martin)*

A-7s were used to maintain pilot proficiency until F-117As became available and were also used as chase aircraft.

Specialist support equipment

The unique characteristics of *Senior Trend* necessitated the construction of several specialist pieces of support equipment. On 1 February 1979, design of the first of three maintenance vans was started. These were delivered to the Air Force on 21 September 1981, 17 June 1982 and 15 May 1985, respectively.

On 12 September 1985, go-ahead was given for the production of two air transportable equipment vans, known as Elvira I and Elvira II. In addition to providing extra maintenance and support facilities, they also incorporated a complete avionics diagnostic system, which itself was upgraded in the two vans on 4 October 1991 and 13 May 1992, respectively, to reflect changes on the F-117A fleet brought about by the OCIP.



The highly classified nature of *Senior Trend*, particularly in the early days, ensured that the customary award of a wooden factory model to key programme individuals and pilots when they left the programme, was completely out of the question. Instead, a hardwood, handcrafted, faceted block, based on the Rock of Gibraltar, was presented. *(Dave Southwood)*

In March 1984 a contract was awarded for the construction of a Weapons System Trainer, this was accepted by the Air Force in November 1985 and was declared operational on 1 January 1986.

In addition to overseeing the construction programme, Col Bob Jackson also set about recruiting the initial cadre of pilots, as Al Whitley, at that time a Major, recalls: 'My interview occurred in late 1980 at the Nellis AFB Visiting Officers Quarters...In the next few minutes, Col Jackson told me very little about a programme which would involve significant family separation, yet the opportunity to not only remain at Nellis AFB for another full assignment, but also the chance to fly the A-7 again. He didn't say much more, other than I would have no opportunity to discuss it with my wife and that I had five minutes to make up my mind. With no hesitation, I said, "Sign me up." Col Jackson said he'd be contacting me in the future on specifics. That was the end of the interview.

'In the spring of 1981, Lt-Col Jerry Fleming, our squadron commander called me and a couple of the new members of the unit to our remote, secure location in Area II (or Lake Mead Base) of the Nellis AFB complex. He showed me a photograph of the airplane and "briefed me in" on the real mission of the unit. Jerry seemed to really enjoy doing this, for he got to see each individual's reaction to such a new, innovative concept in aviation. His favourite questions were, "How fast do you think it will go?" and "What weapons do you think it employs?" Since the movie Star Wars was a big hit at the box office, and the airplane had that "Darth Vader" look, my first thought was this must be a real fast machine. However, Jerry pointed out the relatively large frontal surface area and hinted speed was probably not its strongest attribute. When I did learn what the airplane was all about, it was somewhat hard to believe. I was genuinely excited and honoured to be part of something that was on the leading edge of technology. I quickly added a new word to my vocabulary that would have a significant impact on the rest of my Air Force career – stealth.'

Col Bob Jackson carried out the majority of early recruiting and it was he who selected Al Whitley, out of his pool of pilots, to become the first operational F-117 pilot. Shortly thereafter, Al and a few other pilots were sent to the Burbank production line to become completely familiar with every facet of the aircraft. In addition, they spent many hours in the static cockpit procedures trainer.

To patrol the outer peripheries of the base at Tonopah, the dedicated USAF security force operated Bell UH-IN 'Hueys', and to commute to work, pilots, housed with their families at Nellis

Aircraft 83-0807 was the first from Lot 5. It was first flown by Lockheed test pilot Dave Ferguson on 13 September 1984 and was delivered to the Air Force on 28 November. *(Lockheed Martin)*

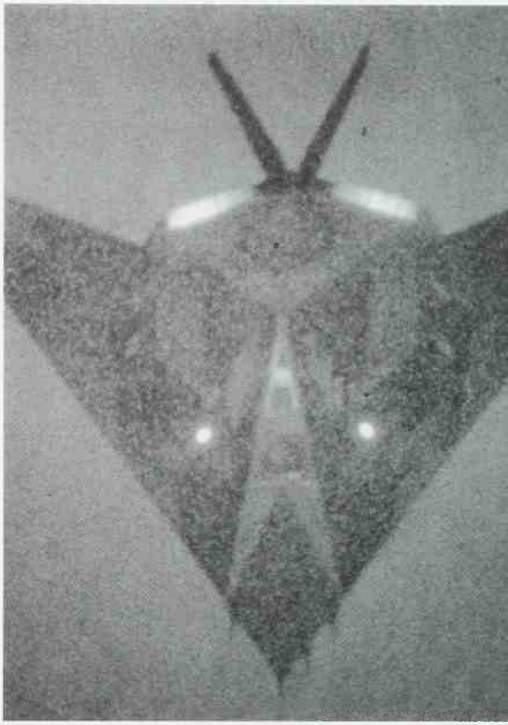
AFB, 306 km (190 miles) away, were transported in on Monday and back home on Friday by Boeing 727s or 737s, belonging to civil contractor Key Airlines. In addition, the 4450th operated three Mitsubishi MU-2 turboprop executive aircraft, used to shuttle small groups between Tonopah, Nellis and Burbank.

The original plan was that the unit should achieve initial operational capability (IOC), 40 months after Aircraft '780's first flight, which was scheduled for July 1980. Therefore Q-Unit, nicknamed the 'Goatsuckers' was expected to assume a limited operational role in November 1982. This was not achieved due to various design and manufacturing obstacles. In fact, as mentioned earlier, the first production aircraft, Number '785, was written-off at Area 51 prior to completing its first Functional Check Flight (FCF) and before being accepted by the Air Force (various remains of '785 were subsequently used to build a gate-guard, which was mounted on a pole and is displayed outside Lockheed Martin

'Ghost Riders' attend a scheduling/training meeting. Pictured left to right are Maj. Mike Mahar (Bandit 304, operations officer); Capt. Skeeter Kohntopp (Bandit 355, scheduler); Capt. Terry Foley (Bandit 327, flight commander); Capt. Mike Mahan (Bandit 323, scheduler); Maj. Rich Treadway (Bandit 336, flight commander); Capt. Gregg Verser (Bandit 310, flight commander); Capt. Steve Troyer (Bandit 334, flight commander) and Maj. Mike Daniels (Bandit 336, assistant operations officer). *(US Air Force)*

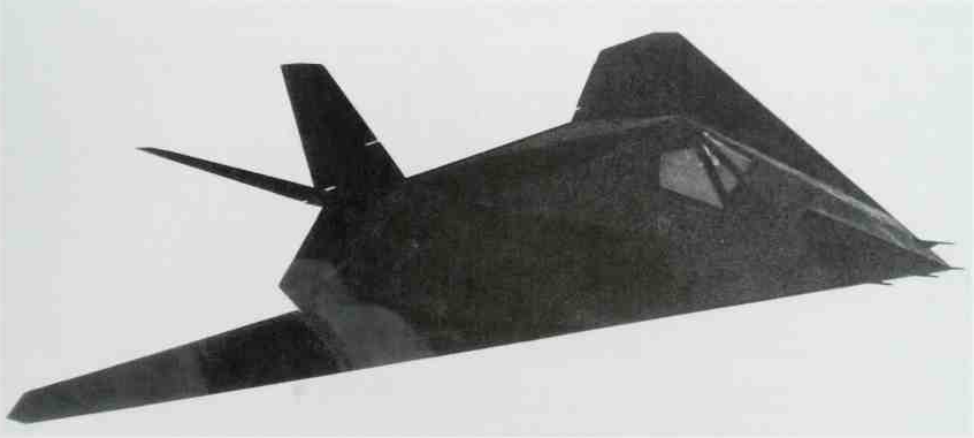
Skunk Works' Palmdale Plant). In the event, it would be aircraft Number Three from Lot 2 that would be first to enter the inventory. First flown by Hal Farley on 20 July 1982, five days after he had flown 80-0786, Aircraft 80-0787 was accepted by the Air Force on 23 August and was joined 11 days later by '786. In September, Det 1 of the 4450th was redesignated as the 4452nd TS and it was while the unit had a complement of just two aircraft that another milestone was achieved. On the night of Friday 15 October, Major Al Whitley conducted his first *Senior Trend* flight and, in so doing, also became the first operational pilot to fly the aircraft.

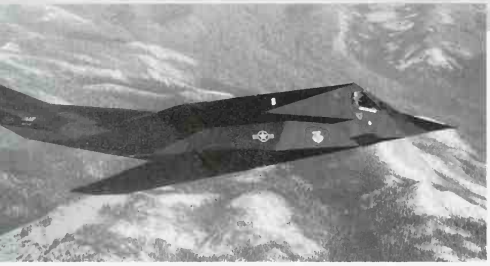
The sporadic nature of the delivery schedule continued, and by the end of 1982, the unit still only boasted seven aircraft. Unlike the *Senior*



Right: To ensure that the *Senior Trend* programme remained in the 'black world' for as long as possible, all early training sorties were flown during the hours of darkness. *(US Air Force)*

Below: This grainy, poor-contrast photograph was the outside world's first glimpse of what this revolutionary aircraft actually looked like. It was revealed by Assistant Secretary of Defense, J. Daniel Howard, at a Pentagon press conference on 10 November 1988 and it took most aviation journalists by surprise. *(US Air Force)*





Above: Delivered to the Air Force on 4 August 1983, 81-10796 is pictured flying a visual circuit of the Tonopah Test Range. *(Lockheed Martin)*

Left: Aircraft 82-0802 was delivered to the Air Force on 6 April 1984. It is seen here over Half Dome, in the Yosemite Valley. *(Lockheed Martin)*

Trend Combined Test Force (CTF) at Area 51, all Tonopah's F-117 flight activity took place at night. Hangar doors were not opened until one hour after sunset, which put the first scheduled take-offs at about 19:00 in winter and 21:30 in summer. For the first year, flights were restricted to within the Nellis range complex, but as confidence grew, flights were cleared off the range. However, in the event of an unscheduled landing, pilots carried a signed letter from a senior Air Force general, ordering the base commander to protect the aircraft. By the end of 1983, 12 F-117As had been accepted by the Air Force and were operating out of Tonopah.

Col James S. Allen had assumed command of the 4450th Tactical Group (TG), from Col Bob Jackson on 17 May 1982, and by 28 October 1983, *Senior Trend* was deemed to have achieved a limited initial operational capability (LIOC). There remained a number of issues that would need to be resolved if the aircraft were to successfully deploy overseas and engage in combat. These included spare parts shortages for IRADS; the weapons delivery software needing further refinement to meet accuracy expectations and overheating of the decking aft of the jet exhaust outlets, which was causing concern should long-range deployments become necessary. In addition, the lack of an automated planning system (AMPS), meant time-consuming manual mission target planning, which dramatically impacted on sortie rates and finally, sheets of BX210 RAM tended to become detached, and it was difficult for the unit to analyse accurately what effect this was having

on the aircraft's RCS. Notwithstanding, by the end of 1982, the potential of *Senior Trend* was apparent to those cleared into the programme and the procurement plan increased to a total of 57 aircraft (the final total was 59). The impact of this decision created the need for two additional squadrons; consequently in July 1983, I-Unit 'Nightstalkers', was activated to be followed in October 1985, by Z-Unit, 'Grim Reapers' (later redesignated the as 4450th TS and the 4453rd Test and Evaluation Squadron (TES) respectively). On 15 June 1984, Col Howell M. Estes, III became the third commander of the 4450th and on 5 May 1985, he led the unit successfully through its first Operational Readiness Inspection (ORI) earning in the process a rating of excellent. Tenure of the unit transferred again on 6 December 1985, to Col Michael W. Harris, it was to prove a period in which events on the world stage threatened to involve *Senior Trend*.

The early- to mid-1980s was a period of world tension. The Soviet Union had invaded Afghanistan and Britain fought a war with Argentina, after the latter invaded the Falkland Islands. Relations between the hawks of the Reagan administration and an apparently equally hostile Kremlin, led by Brezhnev, Andropov and Chenenko, were also at a low ebb. In Europe, Poland began to lurch towards freedom, breaking off the shackles of Communism. But it was the Middle East that was the cause of greatest concern.

No Libyan action

Operation *Eagle Claw*, the attempted rescue by Delta Force in 1980, of 53 US Embassy staff held hostage by the Iranians failed, leaving eight would-be rescuers dead. Iraq attacked Iran, signalling the beginning of a bloody eight-year war. Israel invaded the Lebanon, in a bid to crush the PLO. This led to the US becoming embroiled in peace-keeping duties in the region, which in turn triggered a backlash from various terrorist organisations, many of which were supported by Iran, Syria or Libya. These

The first public unveiling of the F-117 took place at Nellis AFB, on 21 April 1990. On that occasion, two aircraft, one carrying the markings of the 37th TFW commander, the other carrying 415th and 416th squadron markings on either side of the fin, attended a 'meet the people' ceremony frequented by thousands. *(US Air Force)*

attacks included two co-ordinated suicide bombs, in Beirut, Lebanon, which killed 58 French paratroopers and 241 US Marines. The bombing of a TWA Boeing 727, en route from Rome to Athens, killed four; then a bomb attack in La Belle disco, West Berlin, which was packed with American soldiers, killed two GIs and a Turkish woman.

As a direct result of these last two incidents, President Reagan approved a US attack against Libya. By April 1986, the 4450th had taken delivery of 32 Nighthawks and taking into consideration the intense, sophisticated nature of the Libyan defence network, it was deemed that the aircraft's unique characteristics made it an ideal candidate to mount an attack on the country's leader, Col Mu'ammar al Ghadaffi. However, following an intense debate within the highest echelons of power, Secretary of Defense (SECDEF) Casper Wienberger decided not to commit *Senior Trend*, thereby ensuring that its secrets were not compromised.

First Loss

The nocturnal existence of F-117 pilots at this time – sleeping during the day and flying only at night – was both highly demanding and chronically tiring. The root of the problem was the 4450th's flying schedule which, in order to balance pilot proficiency against limited flight-time availability, split the hours of darkness into two 'shifts'. The first wave off, was known as the 'early-go', the second as the 'late-go'. Lt-Col John F. Miller, commander of the 4450th TS, penned a memo on Thursday 10 July 1986, which turned out to be highly prophetic, he observed: 'I believe that these extended hours are taking their toll on overall pilot performance. I have detected more and more instances of poor judgement that weren't evident two to three months ago.'

At 01:13 hours on Friday 11 July 1986, in excellent weather and good visibility, Maj. Ross E. Mulhare departed Tonopah in Aircraft 81-10792, callsign ARIEL 31 and flew north-west to the town of Tonopah. He then turned south-west, continuing his climb to 20,000 ft (6096 m). After crossing the Sierra Nevada Mountains, he turned south and flew along the east side of the broad San Joaquin Valley of central California. Flying in accordance with instrument flight rules (IFR) and in positive controlled airspace, Mulhare carried out radio calls to air traffic control centres at both Oakland and Los Angeles and received clearance to descend to 19,000 ft (5791 m) during the southbound leg. Near Bakersfield he requested and was granted,

Capt. Matt Byrd's (Bandit 348) personal mount supports a new and impeccable paint job. Note that both weapons bay doors are open, but all antennas have been retracted and the fuselage reflectors removed. *(US Air Force)*

At 16330 kg (36,000 lb), with the cg position at 43 per cent, touchdown speed is 149 kt calibrated airspeed (KCAS), at sea level with an outside air temperature of 10°C (50°F). *(Lockheed Martin)*

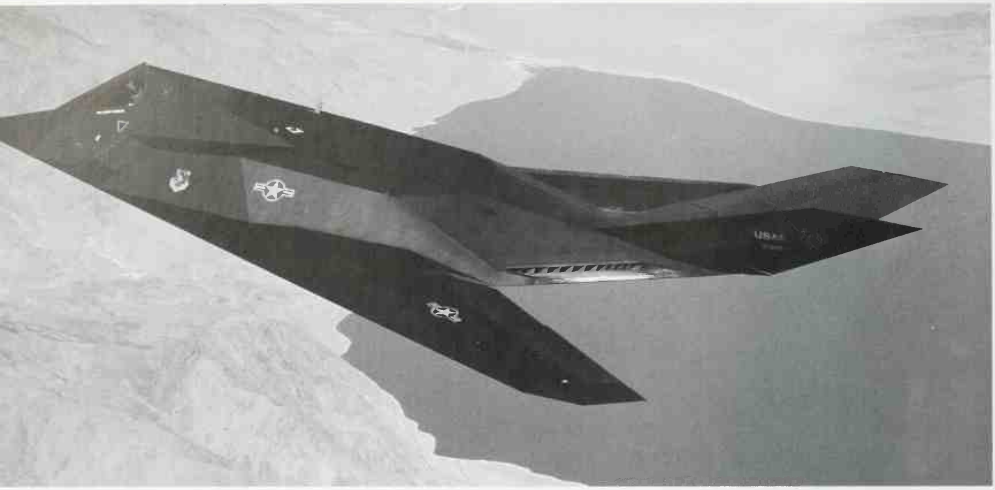
permission to fly 'off-route', in accordance with his pre-briefed mission. The time was 01:44. Just one minute later, '792 ploughed into a hillside at 695 m (2,280 ft) above sea level, killing its pilot.

An accident investigation established that '792 was maintaining a heading of 080° at the time of impact. The aircraft was upright and in a steep dive, characterised as 'no less than 20° and probably in the neighbourhood of 60°'. Impact was at 'high velocity' and both engines were 'operating at high power settings prior to impact'. There was no indication of a pre-crash fire or that Mulhare had attempted to eject. Having received his Bandit Number (Bandit 198) on 7 January 1986, he was declared mission ready on 18 March 1986 and had accumulated 53.5 hours on the F-117A prior to his fatal accident. (A Bandit Number has been allocated to every pilot qualified to fly the F-117, apart from Dave Southwood and Colin Cruickshanks, who flew under the Bandit Numbers of pilots who were absent from the programme.)

In a report submitted to the accident investigation board, Robert McGregor, an aeronautical engineer at the USAF Sacremento Air Logistics Centre stated: 'Without exception, in terms of physical damage to the aircraft, this is the worst crash that I have worked. Structural break-up was almost absolute.' And: 'The right engine compressor drum...was crushed to half its normal length.' The prime reason behind this horrific accident was almost certainly pilot fatigue and spatial disorientation.

On 3 April 1987, the 4450th received its fifth commander, Col Michael C. Short; four months later, Major Jerry Leatherman was recruited into the *Senior Trend* programme and gives his overview of pilot training during that period: 'On a Friday in the first week of August, I had my finny [final] flight in the A-10 [Fairchild Republic A-10A Thunderbolt II] with the 422nd FWS, then on the Sunday, I was driving to Tucson to get checked out in the A-7. That was as far as I knew about the new job, because they weren't briefing anybody until after the A-7 training.

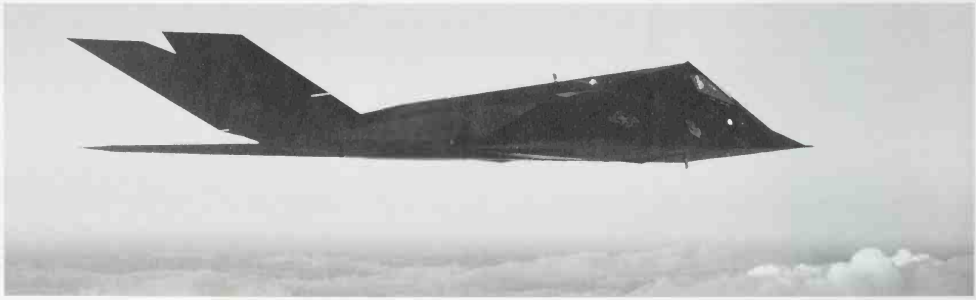
'At Tucson International Airport, I flew with the Guard guys in the A-7, as this was our cover. The A-7 was used because in active duty, nobody flew the A-7, therefore if you landed at another base, there wouldn't be high time A-7 drivers around that could ask difficult questions. I went down for training with Jerry Howalt; we were the only two active duty guys, the rest were being trained to go onto guard units. We started in August and finished at the beginning of November. When we got back to Nellis P-Unit, they gave us a little local area check out, which consisted of five or six rides, flying around Nellis ranges and some low level; basically showing you how to fly around the local area. During that check-out procedure was when they set out a briefing for you. This was when you finally found out what you were going to be doing for a



The lighting angle boldly etches out the contours of 82-0802's fuselage facets as it flies over Lake Tahoe. *(Lockheed Martin)*

living – flying the F-117. There was always a backlog of guys going through the programme, so you didn't get your F-117 check out real quick. In my class they had the first trained civilian contracted instructor to teach the academics and run the simulator programme. One of the things that was unique in training was, before we got to fly the 1-17, they sent us down to Luke AFB and we got a VIP check out in the F-15. We got to fly in the front seat, and did just one ride with no flap landings, because somebody had thought that to do a no flap landing in an F-15 was pretty similar in speed and pitch as the 1-17. So we spent two days at Luke AFB, getting academics and flying the simulator and then our one ride. I started academics for the F-117 in April of '88, so from November to April, I was flying A-7s keeping current. Then in May '88 I took my first flight in an F-117. It was a normal training programme. You had the simulator check-out and then the instrument check-out and then the

During training sorties, two anti-collision beacons are bolted, one each, to the upper and lower fuselage. *(Lockheed Martin)*



The precision-guided munition originally destined for the F-117 was the GBU-10. In its F-117 application, this weapon marries either a Mk 84 or BLU-109 penetrating warhead with a Paveway II guidance kit. The latter consists of a laser tracker and steering canards ahead of the warhead and pop-out wings to the rear. Although GBU-10 remains compatible with F-117, the type's primary weapon has become the GBU-27 (illustrated). Again using either the Mk 84 or BLU-109 warhead, GBU-27 is based on a Paveway III kit, but has been specially modified to allow it to fit the F-117's weapons bays.

mission stuff. You were then assigned to your squadron and you went through mission upgrade, where you had to hit your targets. That was no different from any other fighter-type training that I had been through.'

Before Jerry joined his squadron, the 4450th lost a second F-117A. This occurred on 14 October 1987. Maj. Michael C. Stewart got airborne from Tonopah at 19:53, in Aircraft 85-0815, callsign BURNR 54. The single-ship mission was conducted under visual flight rules (VFR) and remained within the boundaries of the Nellis range complex throughout. At 20:33, three quarters of the way through its mission, the aircraft's radar return [radar reflectors are 'bolted' onto the airframe to allow air traffic control to track the aircraft in training] was seen to stray left of its planned track and disappear. In common with the loss of '792, weather conditions at the time were clear with unlimited visibility.

The crash site was situated on gently sloping desert and the impact created a crater between 1.83 and 2.13 m (6 and 7 ft) deep. The stand-by attitude indicator recovered from the wreckage showed the aircraft to have impacted the ground at an attitude of 28° nose-down and in a 55° banked turn to the right. Yet again there was no evidence of an inflight fire; Maj. Stewart had made no attempt to eject and the aircraft was intact prior to impact. However, unlike the earlier accident, '815's engines were operating at a low power setting. Maj. Stewart had notched up 2,166 hours of flight time, including 76 hours 42 minutes in the F-117; he became Bandit 231 on 1 May 1987 and was declared mission ready 52 days later. As with the earlier accident, the report failed to clearly determine the cause but yet again, repeated references were made to pilot fatigue and disorientation.

Programme manager Paul Martin takes to the podium during a ceremony held at Palmdale on 12 July 1990, marking the final F-117A delivery to the Air Force. At $42.6 million a copy, the aircraft represent incredibly good value for the taxpayer's buck. *(Lockheed Martin)*

Six days after the tragic loss of Maj. Stewart, the 4450th became the centre of more unwanted attention, focused around the loss of yet another of its aircraft. On this occasion, Maj. Bruce L. Teagarden (Bandit 222) safely ejected from an A-7D after the aircraft lost power. Unfortunately, the A-7 crashed into the Ramada Inn Hotel, near Indianapolis airport, killing nine people in the process. Following a detailed accident investigation, however, Bruce was cleared of all culpability surrounding the tragic incident. Although he was publicly acknowledged as being a member of the 4450th, the unit was not known to have any links with Tonopah, ensuring that *Senior Trend* remained in the black.

On 10 August 1988, Col Antony J. Tolin took over as commander of the 4450th and just two months later, in the run up to a presidential election, the Reagan administration requested the Pentagon to schedule a public unveiling event for the F-117. Such a move would undoubtedly boost George Bush's campaign against Michael Dukakis; in the event, embroiling such a prized national asset in a blatant piece of cheap electioneering infuriated some senior congressmen and the event was delayed until 10 November 1988, one week after the outcome of the election had been decided. On that day, at a Pentagon press conference, Assistant Secretary of Defense, J. Daniel Howard

On 8 July 1992, the 37th TFW was deactivated at the Tonopah Test Range. During a ceremony after the last aircraft had departed the base for Holloman; the 37th's standard was furled and presented by Col Al Whitley to Lt-Gen. Tom Baker, the Commander of the 12th Air Force. *(US Air Force)*

held up a fuzzy photograph of the F-117 and all the rumours about the 'F-19', and its shape, circulated by those who had no clue what they were talking about, were instantly shot to pieces, underlining one of many favoured quotes of Ben Rich, 'Those who don't say, know. Those who say don't know.'

Now that the general shape of the aircraft was no longer classified, the 4450th began daylight flights, which naturally led to sightings being reported. On 12 April 1989, ten of the aircraft were observed flying separately at eight-minute intervals, maintaining an estimated altitude of between 1524 m to 1829 m (5,000 to 6,000 ft) and a west to east track. The sighting took place a few miles north of Edwards AFB and a further six F-117As with their lights on adhered to the same route, between 22:00 and 23:00, later that night. Further similar sightings took place in the same general area six days later.

Easing *Senior Trend* into the 'white world', had other spin offs. Gone was the need to shelter the 4450th covert activity behind a valid aircraft type. Consequently in September 1989, the Wing said farewell to its trusty A-7s and instead began operating far more economical and fuel-efficient T-38A Talons, which in turn were later replaced by AT-38Bs, in the chase/pilot proficiency role. This was followed by yet another change on 5 October 1989; the 4450th TG, together with its component squadrons, was redesignated. The parent designation was changed to 37th Tactical Fighter Wing (TFW) (formally an F-4G wing), the 4450th 'Nightstalkers' and the 4451st TS became the 415th 'Nightstalkers' Tactical Fighter Squadron and the 416th 'Ghost Riders' TFS, respectively. The training unit, the 4453rd 'Grim Reapers' Test and Evaluation Squadron (TES), continued its flight training responsibility, but as the 417th 'Bandits' Tactical Fighter Training Squadron (TFTS). The new designations had a firm foothold in a proud history, being the first US night-fighter squadrons of World War Two.

First RAF exchange pilot

The special relationship that exists between the United States and Great Britain has provided a basis for pilot exchanges in even the most sensitive programmes. Graham Wardell attended officer training at RAF Cranwell in 1976, having received a Bachelor of Science degree in Aeronautics and Astronautics from Southampton University. He completed his initial training in BAe Hawks at RAF Valley Anglesey, North Wales, and his weapons training in Hawker Hunters at RAF Brawdy. His first operational assignment was with No. 14 Squadron, at RAF Bruggen, West Germany flying SEPECAT Jaguars. In 1982 he was assigned to No. 41 (Recce) Squadron, again flying Jaguars, but now from RAF Coltishall, Norfolk. As a Deputy Flight Commander with five years operational flying, Graham's next posting was as an instructor pilot on Panavia Tornados at the type's Operational Conversion Unit (OCU), at RAF Honington, Suffolk. In 1987 he was successful in his application to undertake a test pilots' course and was particularly pleased when he was informed

that this would be as an exchange officer, with the US Navy at Patuxent River (Pax River). However, before taking on the assignment, he was offered the opportunity of a lifetime and became the first RAF Exchange Officer in the *Senior Trend* programme. Having flown from Washington to Las Vegas, he met George Doran, who had served as a USAF exchange officer, flying Tornados at Honington, before disappearing off to fly the A-7! He then travelled down to Tucson, Arizona and there joined the 162nd Tactical Fighter Group (TFG) to undergo A-7 conversion training with the Air National Guard (ANG). He completed his first flight in a two-seat A-7K on 20 June 1988. The course lasted 30 hours, after which he joined the 4450th TFG at Nellis, in August. Graham successfully completed his first flight in A-7D 74-1760 on 11 August and flew his first night air tanking in a two-seater A-7 just a week later. He continued flying the A-7 throughout October, before moving on to the F-117 in November. With ground school out of the way, his first 1-17 flight was in 84-0809 on 14 December, when he became Bandit 282. The flight lasted one hour and 30 minutes, during which time he was chased by an A-7. He considered the modest power output from the 1-17's engines at take-off to be similar to that of the Jaguar, adding, however, that with Tonopah situated at 1676 m (5,500 ft) above sea level and with temperatures in excess of 32°C (90°F), he had seen some unbelievable ground speeds displayed on the INS!

Graham commented that: 'A typical working day would begin at 3 p.m. with a basic brief and target study. The targets would be anything from a hangar at the end of a runway, to someone's garage in the middle of LA. As for material, in theory you could use whatever you wanted; long-range angle shots from roughly the attack direction, overhead shots and satellite material. These would provide a lead into the target, the idea being that you had to train your eye to pick up from the photo or image, what would show up in the FLIR to guide you onto the target. The entire attack process was videotaped and assessed as to whether the target was hit or not. My great rival was Greg Feest, an ex-F-15 driver. As much as I tried, I just couldn't beat him, he seemed to have a natural flair for it.'

Graham Wardell was the first RAF exchange officer on the *Senior Trend* programme. *(British Aerospace)*

Following the unit redesignations, Graham finished up in August 1989 in the 415th TFS of the 37th TFW, reporting to Bill Lake, until Lake's departure in November 1989, when he was replaced by Ralph Getchel. Graham's time with the 415th came to an end shortly after the unit departed for a location in the Middle East; he returned to the UK and completed a test pilot course at RAF Boscombe Down, before leaving the RAF and working as a test pilot for BAe at Warton. He was tragically killed on 6 June 1999, whilst demonstrating Hawk 200 ZJ201, at Bratislava Airfield, in the Slovak Republic.

4. Operational History: War and Beyond

Just Cause

Indicted by two Florida grand juries on charges of laundering drug money, Panama's military dictator, Gen. Manuel Noriega, dismissed the country's president, and then ordered his 'Dignity Battalion', to beat up opposition candidate Guillermo Endara. Endara won the Presidential election, but Noriega prevented him

On 19 August 1990, 22 F-117s from the 415th TFS arrived at Langley AFB, VA on a one night stop-over, en route to King Khalid AB, Saudi Arabia. The next day 18 of the aircraft resumed the journey, the remaining four, having completed their duty as airborne spares, returned to Tonopah. *(US Air Force)*

Below: Greg Feest was the first pilot to take the F-117 into battle, during Operation *Just Cause*. He also dropped the first bomb at the start of *Desert Storm* – coincidentally, he flew aircraft 85-0816 on both occasions. *(Greg Feest)*

Above: Major Jerry Leatherman (Bandit 259), was Assistant Chief of Weapons and Tactics for the 37th TFW during *Desert Shield/Desert Storm*, a job for which he was justly awarded the 1991 Chennault Award. He is pictured here standing below F-117A, '785 that was refurbished after its crash and mounted on a pole outside the Lockheed Martin Skunk Works head office at Palmdale. *(Paul F. Crickmore)*

from taking office. On 5 October 1989, an attempt to oust the loathsome dictator failed and throughout the following day, the coup leaders were rounded up and executed. United States/Panamanian relations continued to deteriorate to a point where, on 15 December 1989, Noriega declared a state of war between the two countries. The following evening Panamanian Defence Force (PDF) troops killed a Marine Lieutenant and arrested a Navy Lieutenant and his wife, who had witnessed the shooting. The officer was beaten and his wife threatened with sexual abuse.

The Bush administration decided that the despot had to be removed and issued orders to invade Panama. The objective was to strike at PDF forces, capture Noriega and rescue political prisoners.

Since joining the *Senior Trend* programme, Greg Feest's highly competitive nature and ability had

Successful integration of the F-117's IRADS and the GBU-27, produced the most survivable, accurate and cost-effective weapons system in military history. *(US Air Force)*

ensured he won the squadron 'Top Gun' award for two consecutive years, while maintaining an incredible 100 per cent hit rate. Recognised as the 37th TFW 'Top Gun' for 1989, Greg was selected to lead the Wing's planning effort for Operation *Just Cause*, as the US invasion of Panama had been code-named. As mission lead for the operation, he became the first to employ the F-117A in combat.

Panama did not have a radar defence network, the reason for deploying the F-117 on this mission was based upon its bombing accuracy, and on the night of 19 December 1989, eight F-117s from the 415th TFS took off from Tonopah. Two aircraft were airborne spares and returned to Tonopah following the initial air-to-air refuelling (AR), while two aircraft in the lead cell were targeted to attack an army base at Rio Hato, 105 km (65 miles) south-west of Panama City. The four remaining aircraft were to take part in an operation that remains classified, but involved special forces capturing Noriega; this element of the mission was later cancelled when intelligence reports indicated that the target was not at any of the known sites. The 4848-km (3,000-mile) round trip required five ARs, which were provided by KC-10s from the 22nd Air Refuelling Wing (ARW), out of March AFB. This ever dependable unit actually escorted the 1-17As from Tonopah, all the way down to the Panamanian coast and back! The objective of Major Greg Feest, flying Aircraft 86-0816, and his wingman Major Dale Hanner (Bandit 239), was to drop two weapons in an open field adjacent to barracks belonging to Battalion 2000, a unit known to be loyal to Noriega. The purpose was to stun the sleeping soldiers and disorientate them before they had an opportunity to engage parachute landings by the 2nd, and elements of the 3rd, Ranger Battalions.

However, three hours before the invasion was due to begin, the PDF was tipped off and had deployed to one of the Rangers' objectives – an airstrip. As the two 1-17s approached their target area, the wind changed direction, a target change was called, causing confusion, and the subsequent bombing was not as effective as had been planned. The Chairman of the House Armed Services Committee, Les Aspin, later stated that target acquisition problems had also added to the pilots' confusion because: 'The humid, varied, vegetation...lowered the contrast and gave the [IRAD] system problems.'

Despite the inauspicious start, General Steiner, the XVIII Airborne Corps' commander who had planned the invasion and requested the F-117As, maintained that, despite the PDF having already deployed, the explosions still produced considerable confusion. Several Rangers were killed however, and more than a dozen wounded, in the ensuing fire-fight, before the island could be secured. As for Noriega, having initially taken refuge in the papal nunciature, he was eventually extradited to Florida.

The rather inauspicious debut made by the 1-17 during Operation *Just Cause* paled into insignificance thirteen months later.

Desert Storm

At about 02:00 (Baghdad time) on 2 August 1990, three Iraqi Republican Guard divisions invaded Kuwait. One division thrust down the coastal road to Kuwait City, a second seized inland oil fields and the third sealed off the Kuwait/Saudi

border. The size and the power of the Iraqi onslaught overwhelmed the small state. Elements of the Kuwaiti army and air force fought valiantly for up to three days before lack of fuel and ammunition compelled them to surrender. In just four days Iraq had secured the annexation of Kuwait and its units were amassed, menacingly along the Kuwait/Saudi Arabia border. A successful invasion of Saudi Arabia would not only establish Iraq as the secular leader of the Arab world, but would also result in its controlling 45 per cent of the world's oil. Over the next four months, countless resolutions condemning Iraq were passed at the United Nations, culminating in Resolution 678, which approved the use of all necessary means to drive Iraq from Kuwait after 15 January 1991 – a vote carried 12–2 in favour.

Initially, King Fahdibn Abd al-Aziz Al Saud of Saudi Arabia was not convinced that Saddam Hussein had aggressive intentions towards his country. However, following a series of border incursions, together with satellite imagery provided by the United States showing Iraqi troop positions along the Saudi border, the Saudis relented and conceded that an Iraqi invasion was probably imminent. The King invited Western troops into Saudi Arabia on 6 August and within two days, F-15C Eagle fighters from the 1st TFW, at Langley AFB, VA, KC-10 Extender tankers, E-3 AWACS and C-5 Galaxy transporters carrying advanced elements of the 82nd Airborne Division had arrived to draw 'a line in the sand'. Operation *Desert Shield* had begun.

Back at Tonopah, Col Tony Tolin's tenure on the 37th TFW was coming to an end. In August he would take up his new assignment at Langley AFB and after an absence of five years, Col Al Whitley was to assume command of the F-117 wing for a second tour. Following the change of command ceremony at 10:00 on Friday

Parked in a reveted taxiway at King Khalid Air Base, with the F-117's unique four-section ladder in place for cockpit access, this aircraft is being readied for operations after the sun goes down. *(US Air Force)*

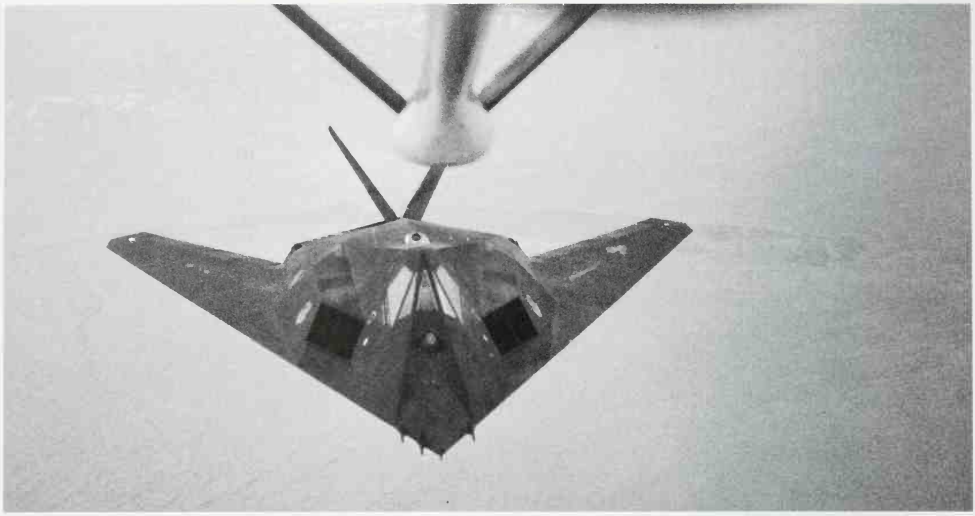
Two Nighthawks taxi out to the holding point prior to launching another raid from Tonopah East. *(US Air Force)*

17 August 1990, Al received a 'phone call to proceed immediately to the command post for a priority message – notification of the deployment order had arrived and he had been tasked to deploy one of his squadrons (the 415th TFS), on Sunday morning.

Maj. Jerry Leatherman and Capt. Marcel Kerdavid were the wing's weapons officers, and together formed the nucleus of a contingency planning group. Jerry remembers: 'I called up Tonopah, to find out if they needed me. They sent a C-12 down to pick me up, because part of my job in the wing was to plan missions for the F-117. I went up and phoned through to the "Checkmate" planning staff in the Pentagon. They had drafted in Mike Ritchy, one of our ex-F-117 drivers, who was calling me and asking me to run stuff through our flight planning computers. He'd ask, "If we place you here, how much gas would it take for you to get to Baghdad and back?" They needed to know in order to get a base for us and secondly, when they got a base, they needed to know how much gas we would need to hit the targets and come back. I spent a lot of time on the secure phones passing back the information they requested. We did all this in an area up at the wing called the "rubber room", so called because the inside walls were soundproof. This wasn't new, it was where we did a lot of our covert planning stuff. It was set up to be self-contained. The big delay for the deployment was mainly from Checkmate figuring out how and where they wanted to base us. Once they had that figured, we were off.'

By Galaxy to Saudi Arabia

A C-5 Galaxy departed Tonopah early on Sunday morning. Among those on board were the mission planners, including Jerry Leatherman, and Col Al Whitley who recalls: 'Lt-Col Ralph Getchell, 415 TFS commander, accompanied me and did one heck of a job of bringing me up to speed on his unit's capabilities. It was on that deployment that he suggested the title of "Team



Lights on the upper wing surface and fuselage, together with a rearward-facing light housed in the apex of the cockpit canopy, aid tanker boom operators in their AR task. *(US Air Force)*

Stealth", which we would use throughout *Desert Shield* and *Desert Storm*.'

At 06:45 on Saturday morning, KC-135 tankers from the 9th Strategic Reconnaissance Wing (SRW), based at Beale AFB, CA, began lifting off the runway and heading for the first air refuelling control point (ARCP). This allowed them to rendezvous with their black single-seat charges. Twelve tankers, including an airborne spare, were organised into three cells and provided tanker support for 22 F-117s. Cruising at 6706–7620 m (22,000–25,000 ft), a total of three ARs per aircraft was needed to complete the initial leg of the deployment to Langley AFB. Around mid afternoon on Monday 20 August, the F-117s were again airborne, this time for the 15-hour, non-stop haul to Saudi Arabia. On this occasion, tanker support was provided by KC-10As of the 22nd ARW, from March AFB. After successfully completing the initial AR shortly after take-off, four of the 22 'Black Jets', designated as airborne spares, peeled away from the formation and headed back to the eastern seaboard. The main formation, led by Lt-Col Greg Feest, then continued east, for King Khalid AB, where they arrived around noon local time, on Tuesday 21 August. Their operating base, King Khalid AB, soon nicknamed 'Tonopah East', nestled within the Asir Mountains, at an elevation of 2065 m (6,776 ft) above mean sea level, just outside the small city of Khamis Mushait. Located in the extreme southern tip of Saudi Arabia, the base was state of the art and well beyond the range of Iraqi 'Scud-B' missiles. The only downside was the flying distance to Baghdad, which necessitated three ARs per sortie, with a typical mission lasting five hours.

On 26 August, the 414th TFS established another milestone when it assumed alert duty for the first time in its history. This consisted of between six and eight aircraft at any one time fuelled up, bombed up and ready to go. The pilots had their flight plans and target photos ready and if the Iraqis decided to roll into Saudi Arabia a robust defensive plan was in place.

As the air armada ranged against Saddam

Hussein continued to build, work on exactly how this awesome force could be used to maximum effect for minimum losses, proceeded in parallel. On 5 September, General Buster Glosson presented the air campaign plan to General Schwarzkopf, who enthusiastically endorsed and approved it.

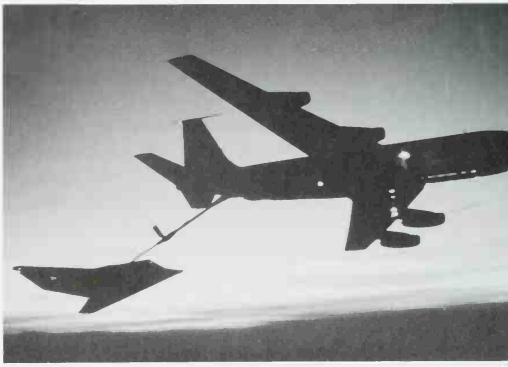
Meanwhile, Air Force aircraft acted as 'ferrets' flying to Iraqi border areas to stimulate Iraqi air defences. This enabled satellites, Rivet Joint RC-135s, Compass Call Lockheed EC-130 Hercules and U-2Rs to record communications intelligence (Comint) and electronic intelligence (Elint), enabling intelligence officers to map the shape and structure of Iraq's electronic air order of battle (EAOB).

Iraqi air defence network

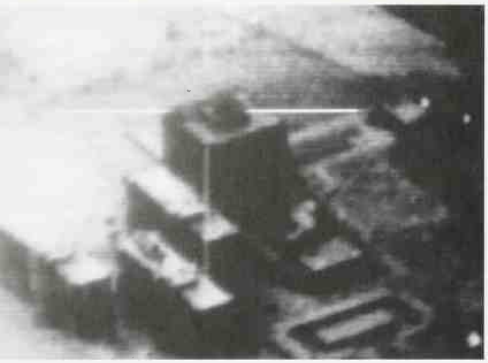
The sophisticated nature of the Iraqi air defence network was briefed to Checkmate and the Joint Chief of Staff (JCS); its destruction would chronically disable the Iraqis' tight central control system. Its various layers consisted of over 400 observations posts from which basic heading and altitude data could be simply sent to a command post. This data was supplemented by 73 radar-reporting stations, which in turn fed into 17 intercept operations centres (IOCs). These command posts were mobile units, often located in hardened concrete shelters, and could process such inputs using computer technology that permitted air defence officers to transmit targeting data via the touch of a light pen to another controller's radar screen. Four sector operations centres (SOCs) then controlled the IOCs. From these three-story, reinforced concrete centres, the defence of enormous areas of Iraq could be planned. One SOC was located at airfield H-3 in western Iraq, another, defending the south, was situated at Tallil air base. The north was covered by the SOC at Kirbuk and the fourth, at the Taji military base, protected the country's interior and Baghdad itself (work on a fifth SOC at Ali al Salem air base had begun, but the unit never become operational). This basic targeting information was then supplied to missile batteries, thereby minimising the time they needed to operate their radars in target acquisition mode. This, in turn, provided the batteries with a degree of defence against an attacker's anti-radiation missiles – these acquire their targets by locking onto the missile battery's radar emissions.

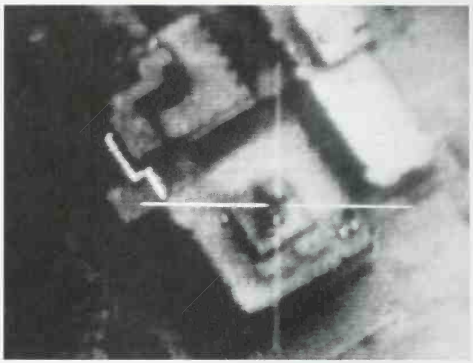
In the hope of avoiding detection by these long-range integrated systems and possible engagement by high- and medium-altitude surface-to-air missiles (SAMs), an interdictor might elect to fly a low-level flight profile. This option the Iraqis endeavoured to seal off, by complementing their defence system with Soviet SA-16, SA-13, SA-9 and SA-7 heat-seeking missiles, SA-8 and SA-6 low-altitude radar-guided SAMs and literally thousands of 57-, 37- and 23-mm anti-aircraft artillery (AAA) batteries. To knock down their target, the AAA units did not independently target an aircraft, but instead, employed the Soviet technique of setting up a 'wall of steel', or barrage, in their sector, allowing the aircraft to fly into it.

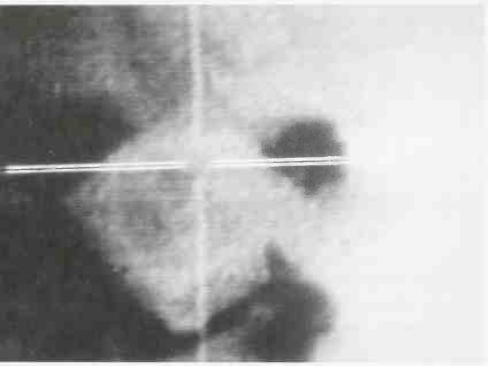
Statistics gathered from post-World War Two conflicts showed that 85 per cent of all aircraft losses occurred within 19 km (12 miles) of the target area and were attributed to AAA or



Once on the boom, lights on the underside of the tanker help to ensure that the receiver remains in the correct position. *(US Air Force)*







Capt. Mark Lindstrom (Bandit 307), attacked the new Iraqi air force headquarters building. These views, recorded from his aircraft's IRADS, depict perfect tracking of the target, culminating in black smoke billowing out from the building, as the weapon blows out all four of its sides. *(US Air Force)*

shoulder-fired SAMs. With a strong likelihood of similar losses occurring over Iraq, General Glosson ordered that low-level missions flown during the first two nights would give way to strikes conducted at medium and high altitude – beyond AAA range, from day three onwards – the exception to this being F-117 sorties.

Carving out this 'medium altitude sanctuary' was a laudable pursuit, but its creation necessitated the dismembering and destruction of the air defence system. The military nomenclature for such an exercise is SEAD (suppression of enemy air defences) and the basic principles of its successful prosecution were highlighted in a classified memo compiled by Glosson and two other planners, before being sent up the line to General Schwarzopf and the JCS. The attack had five objectives: destroy/disrupt command and control (C^2) nodes; disrupt electronic warfare (EW)/ground-controlled intercept (GCI) coverage and communication; force air defence assets into autonomous modes; use expendable drones for deception; employ maximum available high-speed anti-radar missile (HARM) shooters.

In a manner similar to dismembering an octopus, the SOCs and IOCs (the animal's head) that ran the defence network, would be taken out by the F-117s at the outset, as would key early warning radars and communication links; the flaying tentacles would then be dealt with by other, non-stealthy assets. If successful the plan would have two benefits; without the integrated defence network, SAM batteries would be forced to use their radars longer, making them more vulnerable to attack from anti-radiation missiles and, cut off from their GCI controllers, Iraqi fighter pilots would become easy prey for Allied air defence assets.

If it should prove necessary to go to war in the Gulf, it would be the F-117's first true

operational test. General Buster Glosson takes up the story: 'The initial 24 hours of the Gulf War was meticulously planned. I directed the planners to ask themselves three questions about every target they considered: what system had the highest probability of destroying it; what system had the highest probability of its pilot coming back alive, and what system had the highest probability of avoiding civilian casualties. As you may expect, 99 per cent of the time, the answer to these questions was F-117. We did not have enough F-117s to attack every target. So, I directed the F-117 to be used against the most critical, the most highly defended and difficult to hit targets. That gave us the greatest probability of accomplishing our strategic objectives and creating the utmost confusion and disruption. I used all the other systems, be they cruise missiles, fighters or bombers, as fillers.'

Satellite controversy

On 22 September, two C-141 StarLifters delivered the 37th TFW's avionics maintenance vans from Tonopah to King Khalid AB. The unit also boasted its own satellite link to national intelligence assets. This provided it with the threat information needed for the F-117's mission planning system, but did not go down at all well with Central Air Force (CENTAF) intelligence officers, as they intended to control the flow of all intelligence resources and information to the units deployed to the region. Elements within CENTAF therefore worked with the appropriate government agencies to shut the 37th TFW down. When CENTAF refused to reinstate the unit's collection capability, the 37th started using the address of a duplicate system located at Tonopah. Unfortunately for the F-117 unit, CENTAF eventually learned what had been going on and tension over the issue persisted until better communications between the two led to a more co-operative atmosphere. Although such instances were an exception to the rule, it demonstrated a lack of understanding or appreciation of the Wing's unique requirements, born from the need to develop such stand-alone systems in isolation, in the 'black world'. On 8 October, General Glosson described the problem as CENTAF intelligence arrogance and stupidity. He directed Col Whitley to get the best planning information available, whatever the source.

October 3rd saw the execution of the first of three exercises, code-named *Sneaky Sultan*, aimed at testing 'Team Stealth's' ground support functions. In November, the unit also participated in a major six-day exercise, codenamed *Imminent Thunder*, during the course of which it flew 32 sorties. As the weeks ticked by, it was decided that the 415th's sister squadron, the 416th 'Ghost Riders', should be committed to *Desert Shield*. Consequently, on Sunday 2 December, it, like the 415th, positioned to Langley AFB. At 19:03 the following evening, the 416th's squadron commander, Lt-Col Gregory Gonyea, got airborne, leading a six-aircraft element and headed for the first ARCP. These first aircraft were followed 30 minutes later by another six-ship element; there then followed two four-aircraft elements, each interspaced by 30 minutes. All 20 aircraft arrived safely at King Khalid the next day, 4 December, despite one aircraft developing severe engine problems on the final leg of the deployment.

Finding out if it really works

The planners were eager to check on the effectiveness of stealth technology, as Major Jerry Leatherman recalls: 'Towards the latter months of *Desert Shield* myself and Marcel Kerdavid, were one night given a mission that only Col Whitley, Marcel and I knew about. We rendezvoused with a KC-135 that came out of Riyadh and got gas, we then flew towards the border, basically mimicking the tanker tracks that we were going to use during *Desert Storm*. At the same time, the guys at Riyadh had EC-135s, RC-135 Rivet Joint and other intel-gathering platforms airborne at the same time as we were doing this. As we got within 30 miles [48 km] of the border, Marcel and I dropped off

the tanker and 'stealthed-up'. One of us flew at about 10,000 ft [3048 m], the other flew at 15,000–20,000 ft [4572–6096 m] and we flew this mirror image right along the border. We then turned, rejoined the tanker, got gas, and headed back to Khamis. During this exercise, Riyadh noted that the Iraqis seemed unable to detect us. However, they could certainly detect the tankers and when they flew towards them it scared the crap out of them for a few minutes, and they went onto a high alert status. Over the next few months we kept repeating this exercise, flying the same profile, but with different guys from the squadron. This was a bait/decoy thing for the Iraqis, so for weeks they would see tankers going up to the border and doing the same thing, except they never knew that the 1-17s were dropping off and flying along their border. It gave confidence to the guys in Riyadh that we could get in there and back out without being seen, it also gave the pilots a warm feeling that "Hey, this stuff will work."'

So to war

One day in January, at about 10:00 local time, an officer informed Jerry that he was needed in the command post right away. On arrival he was handed a message. He recalls that historic moment: 'I remember it was headed something like Top Secret. It went on to read, "Execute Wolfpack 'H' hour is zero one zero zero, Zulu." Execute Wolfpack was the code for *Desert Storm* to go. "H" hour was to be the start of the war, which was 03:00 Baghdad time. That gave us all our time over targets (TOTs) as these were based on "H" hour. I remember looking at the note and then the two colonels and saying, "Well (just like Slim Pickings, in *Doctor Strangelove*), I guess we got the go code." During the course of the mission cell planning, we split into various teams that concentrated on planning missions for the subsequent night. You couldn't fly the mission you had planned because the planning cycle took anywhere from between 24 and 36 hours. After being awake for that length of time it would have been impossible to fly the mission.

'Joe Bouley was going to be flying the second night, so it was pre-planned that his team was responsible for when we got the go code to finalise the first night's plan. I was told not to tell the other pilots, so I woke Joe up and he dragged his guys over to the mission planning area to start running the final details on the plan, coordinate with the tankers for the rendezvous, etc. After I had got all that going, and with our brief time set for 9 p.m. that evening, I looked at my watch and decided it was time for some sleep...The funniest thing

Above: This warning was prepared by the 18th Psychological Operations Task Force, based at Riyadh. One of several leaflets featuring the F-117, it was dispersed over selected Iraqi air bases and reads: 'This location is subject to bombardment! Escape now and save yourselves.'

Left: All that remains of an Iraqi command bunker, one of many ruins located at airfields visited by F-117s. *(both US Air Force)*

A 'Team Stealth' photograph, taken at King Khalid in late 1990. Front row crouching left to right are: Greg Feest, Rob Donaldson, Lee Gustin, Jerry Leatherman, Wes Wyrick, Ralph Getchell, Barry Horn, Blake Bourland, Bob Warren, Mark Lindstrom, Dan Backhus and Marcel Kerdavid. Back row, standing, are: Clarence Whitescarver, Phil Mahon, Brian Foley, Joe Bouley, John Savage, Bill Behymer, Dave Francis, Kevin Tarrant, Paul Dolson, Lou McDonald, Bobby Bledsoe, George Kelman, Joe Salata and Mike Riehl. *(US Air Force)*

about the briefing was it took less time than one of our peacetime briefings. I think part of the reason for that was, that we were ready to go, everybody had been assigned their targets for months on end, we had been briefing guys on a fairly routine basis of what our plans were, how many guys were going in at any time and the sequence. At the end of it, Col Klause [commanding the F-117 deployment], being a Vietnam veteran and one of the few guys to have flown combat, got up and told us what it would be like to be shot at. He said that we would get a big dry taste in our throat, and the thing was that after it was all over, we would look back and think well that wasn't so bad. He told us to rely on our training and make sure that we did what we needed to do.'

Col Greg Feest recalls the night that validated the stealth technology that would forever thereafter revolutionise air warfare: 'Arriving at the hangar, I proceeded to pre-flight my jet as well as the two 2,000-lb GBU-27 laser-guided bombs strapped in the weapons bay. My crew chief and I did not talk much this night. He and the weapons troops had written numerous messages to Saddam Hussein on the bombs. Hopefully, I'll be able to deliver them, I thought to myself. Having started engines in the blacked-out shelter, my crew chief told me to "Kick some ass!" and he disconnected his communication lead from the aircraft. These would be the last words I would hear until airborne.

'The entire first wave of F-117As launched without radio communications, we didn't want the Iraqis to get a "heads-up" as to our plan. My callsign was THUNDER 36 and my wingman, Captain Dave 'Dogman' Francis was THUNDER 37. We took off and flew to the tanker without saying a word to each other. My radio was on, but remained silent. Since the F-117A is a single-seat fighter, there was no co-pilot to talk to and the next several hours would be extremely quiet. Having rendezvoused with the KC-135 tankers, we air refuelled and headed north, towards Iraq,

The failure of one weapon to penetrate the hardened aircraft shelter (HAS) in the foreground, is more than made up for by three others that did. Note that the doors of all six hangars have been blown out by the blast of weapons exploding inside. *(US Air Force)*

while flying on each wing of the tanker. The night was extremely dark and I was thankful, since I did not want the moon to silhouette my jet as I flew into Iraq.

'At approximately 2:30 AM, I topped off with fuel, 'stealthed-up' my aircraft and departed the tanker. In 20 minutes I would drop the first bomb of Operation *Desert Storm* [The fact that Feest dropped the first bomb of *Desert Storm*, was by no means a coincidence. This action, unbeknown to him, was the result of a personal directive from General Buster Glosson]. Crossing the Iraqi border, I was nervous as I armed my weapons. My target was an IOC located in an underground bunker, south-west of Baghdad, near Nukhayb. This IOC was a key link between border radar sites and the air defence headquarters in Baghdad. Destroying it would allow other non-stealthy aircraft to enter Iraq undetected.

'Approaching the target I was apprehensive. Two thoughts crossed my mind. First, would I be able to identify the target? Second, did the Air Force really want me to drop this bomb? These thoughts only lasted several seconds. I had practised for three years and I could find and

destroy any target within one second of my scheduled TOT. Having trained for so long, nothing was going to stop me from dropping my bombs. All I had to do was play, what I called, a highly sophisticated video game, and, in 30 minutes I would be back in Saudi Arabia.

'As I approached the target area, my adrenaline was up and instincts took over. My bomb was armed and my systems checked good. I found the target on my IR display and concentrated on tracking the target by slewing the cross hairs over the aim-point. The target had been easier to find than I envisioned. I was able to take time to glance outside the cockpit. Everything was dark except for a few lights in the town. It appeared that no one knew I was in the sky. Looking back at my display, my laser began to fire as I tracked the target. I waited for the display to tell me I was "in range" and I depressed the "pickle" button. Several seconds later the weapon's bay doors snapped open and I felt the 2,000-lb bomb depart the aircraft. The bay door slammed closed as I watched the IR display while continuing to keep the cross-hairs on the target. The bomb appeared at the bottom of the display just before it hit. At exactly 2:51 a.m., I saw the bomb go through the cross-hairs and penetrate the bunker. The explosion came out of the hole the bomb had made and blew out the doors of the bunker. I knew I had knocked out the target. The video game was over.

'Having destroyed the target, I turned my aircraft 210° left to head for my second target. While in the turn, I decided to try and see my wingman's bomb hit, since his was due one minute after mine. As I looked back I saw something completely unfamiliar. It looked like fireworks, big bursts of red and orange, flying at me and lighting up the sky. After being stunned for several seconds, I realised it was tracers from triple A. During all my peacetime training missions flying exercises like Red Flag, I had never anticipated what actual triple A would look like. After all it cannot be simulated. I snapped my head forward and pushed the throttles up as far as they would go. I wanted out of the target area as fast as I could.

'As I headed towards my second target, an Iraqi SOC at the H-3 airfield in western Iraq, I looked out in front of my aircraft. I now saw what everybody at home saw on television. Tracers, flashes and flak were all over the place. The whole country had come alive with more triple A than I could ever imagine. I watched several SAMs launch into the sky and fly through my altitude both in front and behind me. But none of them appeared to be guided. Stealth technology really seemed to work! Even if the AAA and SAMs were not guided, the

On 4 December 1990, F-117 representation at King Khalid was increased, when 20 aircraft from the 416th TFS 'Ghost Riders' arrived. *(US Air Force)*

Lt-Col Ralph Getchell (Bandit 287), briefs General Norman Schwarzkopf on some of the 'Black Jet's' intricacies. *(US Air Force)*

intense "barrage fire" in my target area was scary. All it would take was a lucky hit.

'I decided to ignore what was happening outside my jet. I lowered my seat and concentrated on my displays. After all, what I couldn't see couldn't hurt me! I dropped my second bomb and turned as fast as I could back towards Saudi Arabia. I don't think I ever manoeuvred the F-117A as aggressively as I did coming off my second target. For a second time in less than 30 minutes, I wanted out of the target area as fast as possible.

'Having made it safely out of the area, my thoughts turned to my wingman. "Dogman" was again one minute behind me. I knew he had to fly through the same air defences I had just flown through. I didn't think he would make it. For both of us to survive untouched would require too much good luck.'

Having hit both targets, Greg remembers the flight back to King Khalid: 'Just prior to crossing the border into Saudi Arabia, I performed my "destealth" procedures. My task now was to find the post-mission tanker, so I could top off with fuel and make it back to home base. After confirming the tanker was on-station and waiting for my two-ship, I headed for the rejoin point. At a pre-designated time, I called "Dogman" on the radio to see if he was ready to rejoin. I prayed I would hear a response. I didn't hear an answer, so I waited several seconds and tried again. This time I heard him answer. He said he had my aircraft in sight and was ready to rejoin. Now the question was, how many other "Stealth Fighters" would make it home. During our mission briefing, all pilots were give line up cards, these listed all the pilots flying in the first wave along with their callsigns. I had this list on my kneeboard and checked off each name as I heard the pilots check-in with the tankers. After approximately 30 minutes, I looked down at the list and saw I had checked off all the names. All pilots had made it out of Iraq. But had any aircraft been hit?

'It was a two-hour flight back to Khamis Mushait after departing our post-mission tanker. It seemed like it took for ever. Thankfully, the sun was rising so we would be able to land in daylight. The six and one-half hour mission had been quite tiring. Upon landing, I was met by my wife, Capt. Bridget McGovern. During Operation *Desert Storm*, she served as the [wings'] resource manager and was responsible for all of our logistical requirements. She relayed to me that none of the F-117As had sustained any battle damage. She had listened intently in the command post while each pilot called in with his aircraft status before landing. We were both relieved. I immediately told her, for the first time in my life, I was happy I would be mission-planning the next day instead of flying during the second night.' Greg was also met by the 37th's chief of maintenance, who asked him which aircraft he had flown during *Just Cause*. After checking his log book, he discovered that it was the same aircraft that he had just taken into combat over Iraq – Aircraft '816.

The success of the 'Black Jet' was not restricted to attacks on strategic targets in Baghdad and other highly defended targets, as General Buster Glosson recalls: 'I used them to destroy the

Aircraft 80-0790 went on to serve with the 9th FS 'Iron Knights'. *(Lockheed Martin)*

pipelines that fed the fire trenches Saddam intended to fill with oil and ignite as the ground attack started. The F-117 took this option away from him. I also used the F-117 to attack targets others had been unable to destroy. A particular case in point was one of the bridges across the Euphrates, near Basra. Eight airplanes dropped over 36 bombs, and the bridge was still up. I sent one F-117, he dropped two bombs, and disconnected the bridge from both banks.'

On 24 February at 03:00 (local), the Coalition ground assault began. In true *blitzkrieg* fashion, it was all over in just three days. On 27 February Kuwait City was liberated and a ceasefire declared.

At the end of the conflict, General Buster Glosson noted: 'Reflecting on the Gulf War, and specifically the F-117 and what it was able to accomplish; only one word seems appropriate:

A three-ship completes final checks prior to a launch from Holloman AFB. Aircraft 84-0828, in the foreground, was delivered to the Air Force on 17 June 1987. *(Lockheed Martin)*

Lockheed F-117A Nighthawk
49th Fighter Wing

Lockheed F-117A Nighthawk
416th Tactical Fighter Squadron

Lockheed F-117A Nighthawk
49th Fighter Wing

Lockheed F-117A Nighthawk
7th Combat Training Squadron

Lockheed F-117A Nighthawk
37th Tactical Fighter Wing
Colonel Al Whitley
Desert Storm
35 combat missions

Lockheed F-117A Nighthawk
37th Tactical Fighter Wing

Operated by the 415th TFS during *Desert Storm*, aircraft 86-0839 was christened *Midnight Reaper* and completed 39 combat sorties. *(US Air Force)*

awesome. People have said, correctly, that its success was eye-watering. But the real issue is why? The technology, the aircrew training, the willingness of leadership to believe in stealth, and the understanding of what was to be accomplished, all of those things fit together. The single most important accomplishment of the F-117 during the Gulf War, however, was that it saved thousands and thousands of lives. Very close behind is the fact it revolutionised the way we're going to fight wars in the future, and the way people think about wars. Additionally, in the future, belligerent nation states will pause to reflect, before they get carried away with mischief.'

Leading the first element of eight F-117As to return home from King Khalid, Col Al Whitley and two KC-10s, containing 130 support personnel, touched down at Nellis AFB in front of a crowd of 25,000 people on Monday 1 April 1991. During the following months all but a handful of the 37th's F-117As returned home. Those remaining in Saudi Arabia, plus some 100 tactical reconnaissance and support aircraft made up the backbone of Operation *Southern Watch*. To staff the F-117A deployment, a three-month rotation cycle was established for some 200 pilots, maintenance staff and other key personnel.

Move to Holloman

Back at Tonopah, arrangements were being finalised to relocate the 37th TFW to Holloman AFB, NM. The first aircraft to be delivered was 80-0791, which arrived from Tonopah on 7 January 1992, for maintenance familiarisation. However, the move officially got underway on 8 May, when Aircraft 85-0814, flown by Lt-Col 'Moose' Merritt of the 416th TFS touched down. On 8 July 1992, the 37th TFW at the Tonopah Test Range took part in the base's inactivation

ceremony, commensurate with which the 37th TFW was also deactivated and its assets transferred across to the 49th TFW. Simultaneously, command of the F-117A wing was also transferred from Al Whitley to Brig.-Gen. Lloyd 'Fig' Newton. Unusually however, the squadron designations of the F-117A units initially remained unchanged. The move to Holloman at last reunited families, enabling them to join their loved ones in living quarters on or close to the base. It also eradicated the need for Key Airlines to shuttle over 2,500 personnel on 75 weekly flights to and from their place of work – an action that, in itself saved millions of dollars a year.

On Tuesday 4 August 1992, the first Holloman-based F-117A was lost in an accident. Capt. John B. Mills of the 416th FS was forced to eject from Aircraft 82-0801 (not 84-0810 or 82-0802 as reported elsewhere), after it entered an uncommanded roll and caught fire. The crash occurred just 13 km (8 miles) north-west of Holloman, and Mills, a former A-10 pilot, landed safely, just 800 m (0.5 miles) from the blazing wreckage. The pilot then hitched a ride back to base with a highway patrolman, having sustained just a cut chin and a few bruises in the incident. A crash investigation identified the cause of the accident as an improperly reinstalled bleed air duct, which led to a hydraulic line malfunction to the flight controls and a fire.

Force multiplier

The move to Holloman also signalled a steady integration of the F-117A into theatre operational planning, enabling it to become a true 'force multiplier', something that was impossible to achieve during its years 'in the black'. Accordingly, the 416th participated in Exercise *Team Spirit*, a short deployment to South Korea and in June 1993, eight F-117As from the 415th deployed briefly to Gilze-Rijen, in the Netherlands, for Exercise *Central Enterprise*.

For two years after *Desert Storm*, Iraq's Saddam Hussein continued to test the resolve of the West to respond to various provocations. These included cat and mouse games with UN weapons' inspectors; numerous cross-border incursions into Kuwait and a practice of locking onto Coalition aircraft patrolling the no-fly zones established in the north and south of Iraq to protect the Kurds and Shiites, respectively.

On Tuesday 12 January 1993, tired of such games, the Bush administration lost its patience and ordered the 49th's Saudi F-117A detachment to strike against air defence targets. However, owing to bad weather the attack was postponed until 21:15 (Baghdad time) the next day. Six F-117As participated in the measured strike,

Col Al Whitley stands next to 'his' aircraft, 85-0813 *Toxic Avenger*, on his return to Nellis. Displaying the 37th Fighter Wing patch on his left shoulder, he also wears a TAC patch over his right breast pocket. Following an extensive re-organisation of the USAF, TAC became part of a unified command structure known as Air Combat Command. *(Lockheed Martin)*

Lockheed F-117A Nighthawk
9th Fighter Squadron
49th Fighter Wing
Raytheon AGM-154 JSOW
(Joint Stand Off Weapon)

Raytheon AGM-154 JSOW
(Joint Stand Off Weapon)

Lockheed F-117A Nighthawk
Detachmant 1, 5th Fighter Wing
Weapons Testing and Training
Boeing JDAM (Joint Direct Attack Munition)

Boeing JDAM (Joint Direct
Attack Munition)

Lockheed F-117A Nighthawk
37th Tactical Fighter Wing
Paveway II

Paveway II

Lockheed F-117A Nighthawk
37th Tactical Fighter Wing
AGM-65 Maverick

AGM-65 Maverick

Lockheed F-117A Nighthawk
49th Fighter Wing
2,000-lb Mk 84 iron bomb

2,000-lb Mk 84 iron bomb

Lockheed F-117A Nighthawk
37th Fighter Wing
GBU-27

GBU-27

Lockheed F-117A Nighthawk
49th Fighter Wing
Wind Corrected Munitions
Dispenser (WCMD)

Wind Corrected Munitions
Dispenser (WCMD)

Lockheed F-117A Nighthawk
8th Fighter Squadron
49th Fighter Wing
Lockheed Martin AGM-158 JASSM

Lockheed Martin AGM-158 JASSM

Aircraft 85-0816 first flew on 30 October 1985. It is pictured here overflying the hangar area at Holloman AFB. *(Lockheed Martin)*

each equipped with just one bomb. The GBU-27 designated to hit the Al-Amara IOC found its target, however, bad weather again intervened, highlighting the short comings of a non-radar directed, target acquisition and designation system. The aircraft tasked against the rebuilt Tallil SOC failed to locate its target. Of the remaining four aircraft, targeted to hit SA-3 radar sites, one knocked out the unit at Ashshuaybah, two failed in their attempts to hit the Nasiriya site, and the pilot of the fourth aircraft misjudged his turn point, loosing off his LGB into a large, single-storey farmhouse, 1.6 km (1 mile) from his designated target, the radar site at Basra. This action was followed up four days later, by a cruise missile attack against the Za' Faraniyah complex, a site known to be responsible for the manufacture of machinery for Iraq's nuclear programme.

On 30 July 1993, the 415th and 416th FSs were redesignated as the 9th and 8th FSs, respectively. this was followed in December 1993 by a redesignation of the training unit, the 417th, which became the 7th FS.

Following the break-up of the Soviet Union, and in the rush to cash-in the 'Peace Dividend', budgetary considerations and other issues focused the Air Force's attention away from *Senior Trend*. Consequently, the number of war-ready F-117As declined, from 37 out of a fleet of 45 in 1992, to a mere 28 aircraft in 1994. Acknowledging the problem, the Air Force allocated an additional $12 million to help alleviate chronic maintenance shortfalls in 1993; assigning a further $174 million to the programme in 1994.

As the threat of Iraqi aggression against Saudi Arabia faded, so too did Saudi willingness to

Full house. The entire 9th Fighter Squadron, including its 18 'Black Jets', formates behind 'The Boss', Lt-Col Greg 'Beast' Feest, for a photo-call in 1996, at Holloman AFB. *(Col Greg Feest)*

During *Desert Storm*, Aircraft '816 completed 39 combat missions. It is seen here over the deserts of New Mexico. *(Lockheed Martin)*

37th Tactical Fighter Wing
F-117A Gulf War mission markings

49th Fighter Wing

37th Tactical Fighter Wing

49th Fighter Wing

37th Tactical Fighter Wing

49th Fighter Wing

49th Fighter Wing

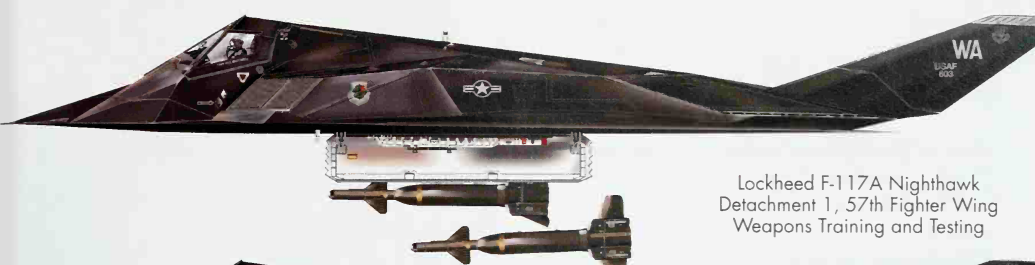
8th Fighter Squadron

7th Combat Training Squadron

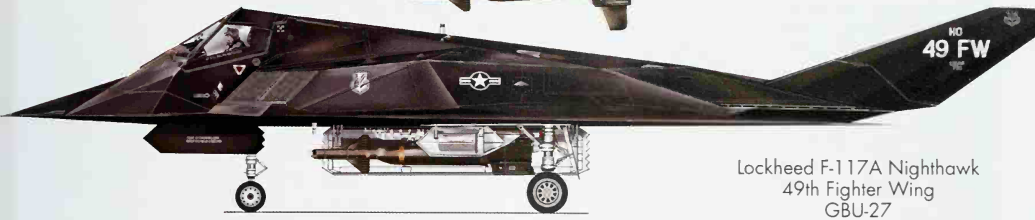
Detachment 1,
57th Fighter Wing

Detachment 1,
57th Fighter Wing

9th Fighter Squadron



Lockheed F-117A Nighthawk
Detachment 1, 57th Fighter Wing
Weapons Training and Testing



Lockheed F-117A Nighthawk
49th Fighter Wing
GBU-27

Desert Storm – Aircraft '794 *Delta Dawn*
35 combat missions

415th Tactical Fighter Squadron
37th Tactical Fighter Wing

Desert Storm – Aircraft '817 *SHABA*
18 combat missions

416th Tactical Fighter Squadron
37th Tactical Fighter Wing

Desert Storm – Aircraft '801 *PERPETRATOR*
38 combat missions

415th Tactical Fighter Squadron
37th Tactical Fighter Wing

Desert Storm – Aircraft '833 *Black Devil*
30 combat missions

416th Tactical Fighter Squadron
37th Tactical Fighter Wing

provide the US with offensive bases. Saddam Hussein, however, remained in firm control of Iraq and the games of brinkmanship continued. In August and again in early September 1996, he ordered vicious attacks against Kurdish factions in northern Iraq. The US responded by firing 44 cruise missiles against four air defence sites in southern Iraq. In addition, President Bill Clinton announced an expansion of the southern no-fly zone, to further help protect Shiites in the region. On 11 September 1996, Iraq fired an SA-6 at two Air Force F-16s patrolling in the northern no-fly zone. In response, SECDEF William Perry announced that four Boeing B-52 Stratofortresses, equipped with cruise missiles, would be deployed to Diego Garcia, a tiny island in the Indian Ocean, and a number of F-117As would also be dispatched to the region. As the Saudis refused to allow the 'Black Jets' to be based in their country, agreement was gained to station the aircraft in Kuwait. Consequently, on 11 September, eight F-117As of the 9th FS, together with its commander, Lt-Col Greg Feest, deployed to Al Jaber AB, Kuwait, in Operation *Desert Strike*. The flight from Holloman was direct and lasted 16 hours, establishing in the process yet another milestone in *Senior Trend's* formidable career – the longest non-stop flight to date.

Aircraft 84-0826 first flew with Dave Ferguson at the controls on 2 March 1987. It was delivered to the Air Force on 25 March and went on to serve with the 9th FS. *(Lockheed Martin)*

More Holloman losses

During the night of Friday 5 April 1995, Aircraft 84-0824 came close to being written off when it was forced to conduct an emergency recovery back into Holloman. The aircraft caught fire and was badly damaged, but the pilot escaped unhurt. Considerable work was necessary by Lockheed Martin to restore the aircraft to an airworthy state, and on 15 July 1995 Tom Morgenfeld successfully completed its FCF.

The 49th TFW lost its second F-117A from Holloman (the fifth to date) on 10 May 1995, at 22:25. Aircraft 86-0822, was being flown by Capt. Ken Levens of the 9th FS, on a night training flight, when contact was lost. The aircraft crashed on Red Mesa, at the Zuri Indian Reservation; the pilot had not attempted to eject prior to the crash, and '822 gouged out a 6-m (20-ft) deep crater upon impact. Having received his Bandit Number (461) on 16 December 1994, Capt. Levens had accumulated just 70 hours on the aircraft prior to the incident. An accident investigation team established that there were no signs of mechanical or electrical failure prior to impact and that pilot disorientation seemed, yet again, to be the most likely cause of the tragedy.

The sixth accidental F-117A loss occurred

This sequence shows the break-up of aircraft 81-10793 as it was being demonstrated by Maj. Bryan 'BK' Knight of the 7th FS, at the Chesapeake airshow, on 14 September 1997. *(both Stan Piet)*

publicly and in spectacular fashion. On 14 September 1997, Maj. Bryan Knight, an instructor with the 7th FS, flying Aircraft 81-10793, was coming to the end of his expertly choreographed display routine, during an airshow at Chesapeake Bay, near Baltimore, Md. Flying at 380 kt (704 km/h; 437 mph) and at a height of between 183 and 213 m (600 and 700 ft), he was entering a 15° climb when the left outboard elevon made at least four rapid oscillations, causing a 0.8-m (2-ft 6-in) section of the inboard elevon to become detached. The aircraft then rolled rapidly left (90° within 0.8 seconds) and then pitched sharply up into a high angle of attack. The landing gear was seen in the down position, and the aircraft was completely out of control. Bryan Knight managed to eject safely before the disintegrating aircraft hit the ground. About a dozen spectators received minor injuries in what could so easily have been a disaster. The subsequent accident investigation determined that the incident had occurred because four Hi-Lok fasteners used to secure the elevon hydraulic actuator to a spanwise, 'Brooklyn Bridge' I-beam, had not been re-installed following maintenance conducted at Holloman in January 1996. Over the intervening 20 months, this subjected the assembly to additional air loads and vibrations, causing three L-brackets and both T-brackets that secured the assembly, to break; this in turn led to the inevitable. A post accident inspection conducted on the rest of the F-117A fleet discovered some loose fasteners, but no missing ones. The accident prompted the Air Force and Lockheed Martin into discussions, to redesign the actuator, enabling its removal while leaving the 'Brooklyn Bridge' I-beam in place.

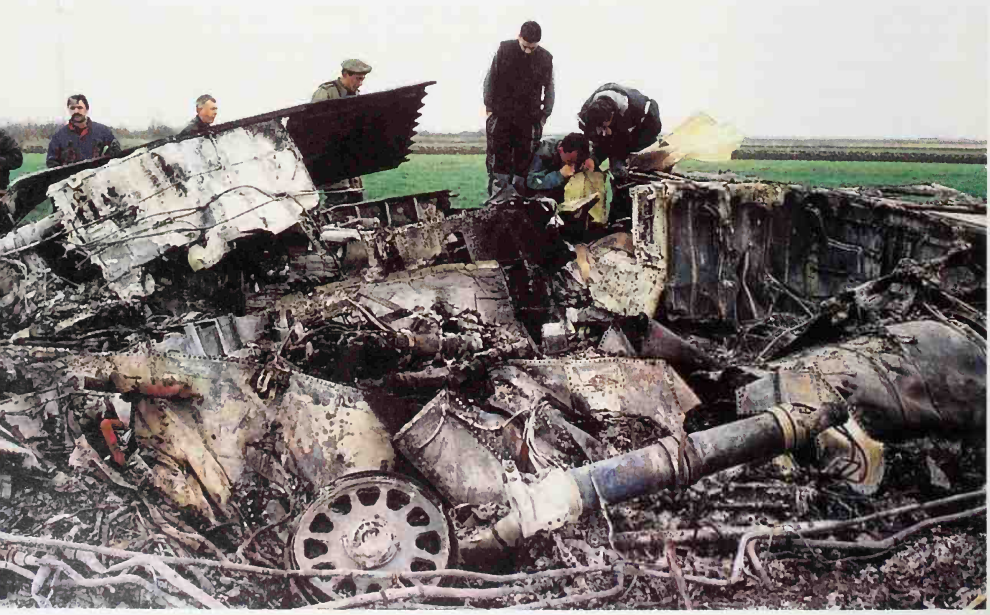
The Balkans

After the collapse of European communism, there were few countries better placed to successfully complete the transition into democracy and a free market economy than Yugoslavia. However, as the small states of Slovenia, Croatia, Macedonia and Bosnia fought for five bloody years to gain independence from Belgrade, President Milosevic cynically manipulated the situation, using nationalism as a means of inciting the large Serbian populations in those states to unite, in the desperate hope of creating a 'Greater Serbia'. On 30 January 1999, NATO stated that it would take whatever steps necessary, including mounting air strikes, to compel compliance with the demands of the international community to achieve a political settlement to the volatile situation threatening to engulf Kosovo. Shortly after the Rambouillet

peace initiative failed, the Serb offensive in Kosovo intensified and NATO Secretary General Javier Solana ordered the NATO Supreme Allied Commander Europe, US Army General Wesley Clark, to initiate air strikes against the Federal Republic of Yugoslavia. On 24 March 1999, the air strikes began, marking both the start of Operation *Allied Force* and the first offensive action against a sovereign nation in NATO's 50-year history. Included in the air armada that had been assembled ready for the necessary orders, were 23 F-117s, based at Aviano, Italy, and a dozen of the black jets hit targets during Day One of the campaign. On Day Four, Serb air defences pulled off the coup of the entire war when, at 19:45, they managed to successfully engage and shoot down F-117A 82-0806, an aircraft allocated to the 8th FS. The pilot managed to eject safely prior to the aircraft crashing to the ground some 64 km (40 miles) north-west of Belgrade. At the time of writing, the weapon responsible for the loss remains officially unconfirmed, although speculation is that it may well have been an SA-3 SAM. At 03:35 on the morning of the 28 March, a US combat search and rescue team was flown into the area in a Sikorsky MH-53J Pave Low III helicopter supported by two Sikorsky MH-60G Pave Hawks, and successfully extracted the Nighthawk pilot, Major Dale Zelco, 16 km (10 miles) west of the crash site.

That the F-117 Nighthawk played a role in this conflict is beyond dispute, however, unlike with *Desert Storm*, to date the powers that be have decided, for whatever reason, that historians and the US tax payer will not be privy to any further information on that role.

On the night of 27/28 March 1999, Aircraft 82-0806 was shot down 64 km (40 miles) from Belgrade, Yugoslavia whilst participating in Operation *Allied Force*. Its pilot ejected safely and was rescued. *(Air Forces Monthly)*



5. Technical Accomplishments

The F-117A is powered by two General Electric F404-GE-F1D2 non-afterburning turbofans. Its external shape is characterised by a modified delta that blends together the wing and fuselage structures, and its two tailfins are canted outboard. The aircraft is 19.43 m (63 ft 9 in) in length, has a span of 13.21 m (43 ft 4 in), stands 3.78 m (12 ft 5 in) to the top of its closed canopy and boasts a modest wing area of 84.79 m^2 (912.70 sq ft). Low observability necessitated a leading edge sweep, which is completely unbroken from nose to wing tip, of 67.3°. When Lockheed test pilot Dave Ferguson first saw the highly faceted, unconventional, 'slab-sided' aircraft, he asked Dick Cantrell, the programme's chief aerodynamicist, how airframe ice encrustation might affect the aircraft's aerodynamics; Cantrell dryly replied, 'Probably improve it.'

The machine's empty weight (including unusable fuel, oil and pilot) is 13381 kg (29,500 lb); this increases to 23814 kg (52,500 lb) at maximum take-off weight – which includes 2268 kg (5,000 lb) of ordnance. On the ground, the F-117 stands on a tricycle undercarriage that has a main wheel track of 4.34 m (14 ft 3 in).

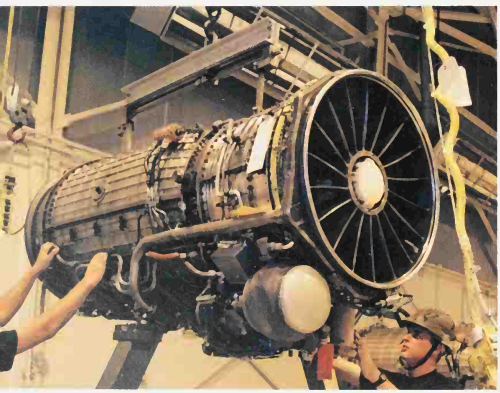
The maximum thrust for each engine is 46.87 kN (10,540 lb st), uninstalled; however, the way in which the exhaust plume is ducted through the slotted exit nozzle, in order to reduce its IR signature, reduces the available power to 40.20 kN (9,040 lb st) when installed in the aircraft. The engine's three-stage, low-pressure compressor fan, together with the

The F-117A is at it most stealthy head on; reflecting incident radiation away from the hostile radar receiver. *(Lockheed Martin)*

The flat undersurface ensures that there are no corner reflectors to advertise the 1-17's presence. *(Lockheed Martin)*

seven stage high-pressure compressor, are each driven by single-stage turbines. Both the first- and second-stage high-pressure compressor stator blades are variable; air bled from the fourth stage compressor is used by the engine anti-ice system; while variable geometry inlet guide vanes (IGVs) mounted in front of both the fan and compressor, direct the flow of inlet air to achieve optimum engine operation. Non-continuous engine ignition is provided by a single igniter; while an engine electronic control unit (ECU) and main fuel control (MFC) provides coordinated engine operation.

An engine accessory gearbox, driven by the compressor shaft, drives the oil pump, engine alternator, main fuel pump and main fuel control, together with an airframe mounted accessory drive (AMAD). Left and right spring-loaded engine blow-in doors, located in the engine inlet ducts, open to allow supplementary air to augment engine requirements at low speeds. These doors close progressively as the aircraft accelerates and are fully closed at about Mach 0.55.



Fuel and oil system

The engine fuel system provides a continuous fuel supply to the combustor manifolds and the fan and compressor variable actuators. Fuel is fed into the engine fuel system through a single inlet connection to the main fuel pump. A small proportion of the main fuel output is used to cool the engine ECU. Having passed through the main

The engines powering the F-117A are a version of the General Electric F404 turbofan which powers the Boeing F/A-18. The variant used in the Nighthawk is the non-afterburning F404-GE-F1D2. *(US Air Force)*

fuel pump, fuel is fed into the MFC and from there into the combustor manifolds and main fuel nozzles. Each engine is equipped with a self-contained oil system.

From the pilot's perspective, there are eight fuel tanks in the F-117A. There are two wing tanks, two forward transfer tanks, two aft transfer tanks and two feed tanks. They are arranged as their names imply, with the feed tanks being situated in the middle, between the forward and aft transfer tanks. Normally, the left feed tank is the source of supply for the left engine and the right feed tank, the right engine. Each feed tank has two AC-driven boost pumps, the aft pump mounted in the sump tank delivers fuel at higher pressure to the engine feed and during negative *g* and/or inverted flight; while the forward boost pump supplies fuel in the event of aft boost pump failure. Fuel is not used to trim the aircraft, this is achieved aerodynamically, using control surface position. However, a controlled fuel burn sequence is utilised to maintain the cg, within limits. A high level of redundancy is built into the fuel transfer system, with each boost pump capable of supplying full fuel flow demands for both engines and should the boost pumps fail, fuel is fed to the engines by gravity. Wing tank fuel is transferred into the fuselage, then the forward and aft transfers push fuel into the feeds. The total fuel capacity is approximately 8256 kg (18,200 lb) or 10599 litres (2,800 US gal) of JP-4 or NATO F-40.

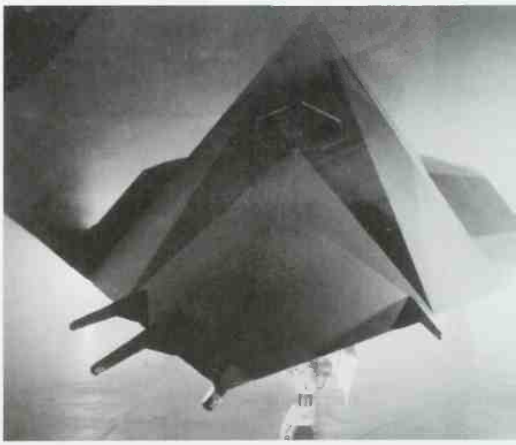
A fuel pressurisation system utilises conditioned engine bleed air from the environmental control system to conduct an inerting agent (halon) through a vent box and into the air spaces above the tanks.

An air refuelling receptacle and its slipway is mounted within the upper fuselage dry bay in the forward transfer tanks and on the aircraft centreline. The receptacle is hydraulically powered and electrically controlled, and when actuated it rotates to the open position. Typical flow rates are 907 kg (2,000 lb) per minute from a KC-135 and 1361 kg (3,000 lb) per minute from a KC-10.

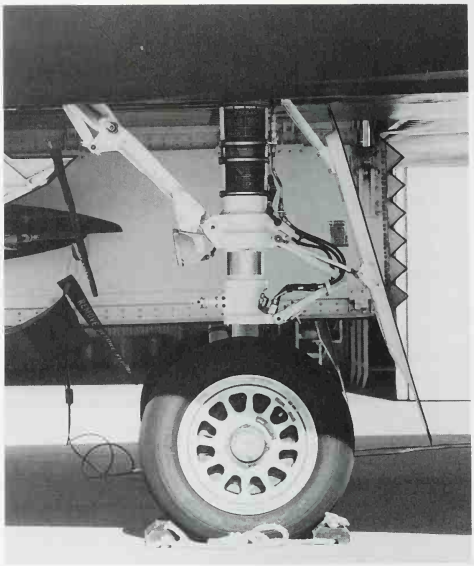
Ignition system

Each engine's ignition system contains one igniter plug and is powered by its respective engine alternator. In order for the alternator to produce enough power for the plug to cause engine ignition, the engine must be spun above 10 per cent RPM (revolutions per minute). Once this has been achieved, the ignition system remains firing until engine power increases above 45 per cent, after which it automatically cuts off (idle power is usually between 62– 64 per cent). In the event of a flame-out, sensors within the engine detect a pressure drop and as the engine winds down below 45 per cent the ignition system again cuts in and remains in operation until engine RPM drops below 10 per cent, at which point the system becomes powerless.

Each engine is controlled by a throttle, mounted on the left console with detents at OFF, IDLE and MIL. The OFF position terminates engine ignition



The unique configuration of the faceted air data probes is readily apparent. Total pressure is measured from a single orifice at the top of each probe. Orifices on the left and right cheek of each front facet measure differential pressure to determine beta. Alpha is resolved by the differential pressure taken from ports situated in the upper and lower front facets, while static pressure measurements are collected from four small orifices located on each probe's side facet, further downstream. *(Paul F. Crickmore)*



The main landing gear tyres are Goodyear 32 x 8.8 26-ply tubeless units. The 1-17's troublesome steel brakes have now been replaced by carbon-carbon brakes on F-15E wheels. These have dramatically enhanced stop performance. *(Paul F. Crickmore)*

and fuel flow. The IDLE position commands minimum unified fuel control (UFC) thrust and is used for all ground and air starts. From IDLE to MIL, the throttle controls the output of the engine.

Hydraulics

Hydraulic power is supplied by two separate systems, namely the primary utility hydraulic system and the primary flight hydraulic system. Each is then divided into secondary systems, designated A and B, which thereby produce utility hydraulic A, utility hydraulic B, flight hydraulic A and flight hydraulic B. If a leak develops, a valve sensing a decreasing reservoir level shuts off secondary system A of the affected utility or flight hydraulic system. If the leakage continues, secondary system A is restored prior to a shutdown of secondary system B.

The flight hydraulic system is powered by two hydraulic pumps, one mounted on the AMAD of each engine. If one engine is shut down, flight hydraulic power continues to be supplied by the flight hydraulic system pump powered by the operating engine. This self same system is used to produce utility hydraulic power. The two flight systems each power three separate control surfaces for survivability. This is further backed up by utility B. Utility A provides the muscle for all other hydraulically activated equipment on the aircraft – the air-refuelling door, nose wheel steering, auxiliary power unit (APU) exhaust door, wipers, landing gear, weapons bay doors, weapons trapeze and wheel brakes. With the APU operating, the emergency power unit (EPU) can provide emergency hydraulic power to the flight hydraulic system when manually selected.

The landing gear is electrically controlled and hydraulically operated. All three undercarriage legs retract forward, thereby providing a free-fall auxiliary extension capability. Nose wheel steering is mechanically controlled via the rudder pedals and is electrohydraulically powered with two steering ranges. The system automatically engages when the nose strut is compressed by the weight of the aircraft and provides a steering range of 10° left or right; however, by pressing and holding the nose wheel steering button on the control stick, the range is increased to 45° left or right.

Electrical system

The generators are the same as those used on the F/A-18. The AC equipment consists of a 115/200-volt, three-phase, 400-Hz system, supplied by two 30/40-kVA, constant-speed generators, one mounted on each engine. DC power is then obtained from two AC-to-DC converters that supply DC power to the left and right main DC buses, the left and right essential buses and the battery bus. Emergency power is provided by a 5-kVA auxiliary generator, which is powered by the EPU, which is itself driven by APU exhaust gases. In the event of a multiple generator and EPU failure, batteries provide power to the flight control system for approximately ten minutes,

during which time an immediate landing is essential, if a complete failure of the fly-by-wire and flight control systems and subsequent loss of the aircraft is to be avoided.

Flight control system

As already discussed, the external shape of the F-117 was determined by the requirement to meet a specific set of low-observable criteria. Its cg locations were determined by its structure, engines, fuel and mission equipment and their locations within the airframe. As a consequence, the F-117 is an aircraft of unusual aerodynamic configuration, high dihedral effect and a large operating range of cg travel. At forward cg – full payload and 1814 kg (4,000 lb) of fuel or less – the type's unaugmented stability and control characteristics are similar to those of a more conventional aircraft. However, at the aft cg position – no payload, full wing, feed and aft transfer fuel tanks – the aircraft would be unflyable without significant artificial stability augmentation through the FCS. Critical to providing an effective FCS is the accurate collection of air data, which is achieved utilising a unique, four-probed pitot/static system. It consists of four similar subsystems, with each nose-mounted probe supplying static pressure signals and total pressure, alpha (AoA), and beta (sideslip) differential pressure signals to the flight control computer (FLCC). The C probe supplies total and static pressures to the air data computer (ADC) that provides data via the dual data multiplex bus to the W-Weapons system computer (W-WSC), for weapon delivery calculations. The B probe supplies total and static pressures to the pilot's stand-by instruments, the latter being completely independent of the static ports supplying signals to the FLCC. These stand-by instruments, located on the left side of the instrument panel, include the vertical velocity indicator, altimeter and airspeed indicator. When the aircraft is on the ground, DC power is used to heat the pitot/static manifolds and associated plumbing to prevent condensation from collecting, and once airborne, the probes are heated by DC power to prevent icing. The four-channel, computer-controlled fly-by-wire system hydraulically positions the control surfaces on pilot command. The aircraft is controlled in pitch and roll through the deflection of inboard and

Forward retracting landing gear ensures that gravity will force the gear legs down if emergency extension is ever necessary. *(Lockheed Martin)*

outboard elevons. Directional control is provided through the two movable fins. Six integrated dual-servo actuators power the control surfaces, one for each elevon and one for each fin. The primary flight controls and trim in all three axes are mechanised as a quadruple redundant command augmentation system with no mechanical back-up. The pilot controls the pitch and roll axes through the conventional movable centre stick; similarly, directional control is accomplished with conventional rudder pedals. The stick and rudder pedal positions are converted to quadruple electrical signals which are then compared with acceleration and rate feedback in the FLCC, which processes and modifies these signals and generates the appropriate flight control surface command signals. These signals are then transmitted to the triple-redundant, electro-hydraulic servo valves in the hydraulic integrated servo actuators that control the individual surfaces. Automatic and manual trim modes are provided for both pitch and yaw axes, however, roll trim can only be achieved manually.

The FLCC contains several limiters that automatically restrict pitch axis manoeuvring to prevent exceeding specified AoA and load factors. For example, full aft stick always commands positive 7 *g*, but the positive AoA limiter overrides the pilot input and restricts the load factor to a lesser value if required by the prevailing conditions. Similarly, full forward stick always commands negative 2 *g*, however, since there is no negative AoA limiter, the pilot must closely monitor such inputs below 200 kt (371 km/h; 231 mph). To further safe guard against exceeding the AoA for any given set of flight conditions, a warning system is fitted which provides the pilot with a variable audio tone through his earphones. A mechanised voice alert warning system provides warnings to the pilot if the Mach/airspeed limit is exceeded, or if the aircraft dips below its minimum en-route altitude.

The autopilot system has both dual channel monitored operation and single channel operation and provides roll and pitch attitude hold, heading hold, Mach or altitude hold and navigation steering capabilities. When engaged, the maximum pitch and roll angles that will be maintained are +/-30° and +/-70° respectively.

Flight instruments

Electro-mechanical flight instruments are provided as a back-up to flight data displayed on the multipurpose display indicators (MDIs). These include an attitude director indicator (ADI), horizontal situation indicator (HSI), altimeter, airspeed indicator (ASI) and a vertical velocity indicator, all grouped to the left side of the instrument panel. AoA and beta indicators are located either side of the upper centre panel and a radar altimeter and turn-and-slip indicator are positioned on the right side of the instrument panel, together with the engine performance instruments and fuel quantity gauge.

Displays

The F-117's cockpit is dominated by four major displays, namely a head-up display (HUD), situated at the top centre of the instrument panel; a sensor display below the HUD and two MDIs located either side of the sensor display.

The HUD combines real-world cues and flight-direction symbology. Focused at infinity, it creates the illusion that the symbols are superimposed on the real world and although the HUD is primarily attack orientated and has specific formats for the various attack modes, it also displays basic flight data, including ILS (instrument landing system) steering data to support ILS approaches.

Originally the two MDIs were identical and displayed a variety of general flight and system information and, under certain conditions, image data. Each MDI had five multifunction switches along each of its four sides. Eight MDI display formats were driven by the WSC, each with variations depending upon the state of the system and each with a specific set of associated switch functions; these formats were grouped into two sets. One set, referred to as the HSD group consisted of the status (STAT) display, the stores management display (SMD), the horizontal

situation display (HSD) and the tactical plot (TP) display. The second set known as the VSD group, consisted of the basic test display, the SMS test display and the vertical situation display (VSD). Typically, the left MDI was used to display one of the HSD group formats while the right MDI had the VSD format displayed, in order to provide good head-down attitude and steering data. However, any format from either group could be displayed on either or both MDIs. Upon entry to an attack mode, the SMD was automatically displayed upon the MDI which had the HSD group selected.

Avionics integration

The integrated avionics configuration of the F-117 has been carefully selected to maximise the effectiveness of the aircraft without compromising the operational advantages gained from the application of low-observability technology. Passive operation in the IR portion of the spectrum was selected as the most viable sensing method. As its designation implies, the IRADS incorporates target ranging, designation and tracking capabilities. A self-contained navigational capability is provided by a highly accurate inertial navigation system and other aids, including TACAN (tactical air navigation) and an ILS have also been provided for use in non-hostile areas. The endgame of these highly integrated systems is to provide single-pilot management and control of a complex aircraft and its mission.

Senior Trend's original avionics package was orientated around three Delco M362 F computers with 32k words of 16-bit core memory, as used in the F-16. Interconnected via a dual redundant MIL-STD-1553 databus, the weapons delivery computer (WDC) was the executive, providing overall control, as well as updating cockpit displays, performing weapon delivery calculations and controlling data distribution. The navigation control computer performed all navigation and control functions, including inertial measurement, navigation and flight director steering, as well as position update, TACAN and ILS interface, etc. The third computer provided control and data processing for a supplementary system and, in addition, provided back-up, should either of the other two computers fail.

Once mission planning has been completed, details are fed into the mission data processing system (MDPS), which is then down-loaded into the expanded data transfer module (EDTM). This is a transportable computer memory module, which is loaded with mission-unique data and is carried by the pilot out to his aircraft. The EDTM is then inserted into the expanded data transfer module interface unit (EDTMIU) and during the pre-flight period, this mission-unique data is loaded into the aircraft's mission computers through a high speed bus. As the Honeywell SPN-GEANS INS navigates the aircraft to the target area, the computer system cues the IR system to the target. Placing the cross-hairs of the aircraft's sensor display on the target and various offsets, the pilot refines the aiming point, laser designates the target and consents for weapon release. The WDC simultaneously performs relevant ballistic calculations, based upon the weapon to be despatched, together with INS and IR inputs. Weapons release then occurs via the stores management system at the appropriate time.

The IRADS is built by Raytheon (formerly Texas Instruments). Two turrets are mounted in 'contour' to conform to set RCS criteria. The target is initially acquired by the FLIR unit, located in the top turret. It is then tracked by a video camera and displayed on the IR targeting screen in the cockpit. As the 'look angle' increases, the target is 'handed-off' to the DLIR, housed in the lower turret. Because the two turrets are identical (and interchangeable), the video picture received by the DLIR has to be inverted electronically when displayed to the pilot, thus enabling the image to remain 'top side-up'. Despite many initial problems, the system is capable of tracking the target throughout dive/toss type deliveries, where it could be subjected to as many as three hand-offs and air loads of 4 *g* during toss manoeuvres.

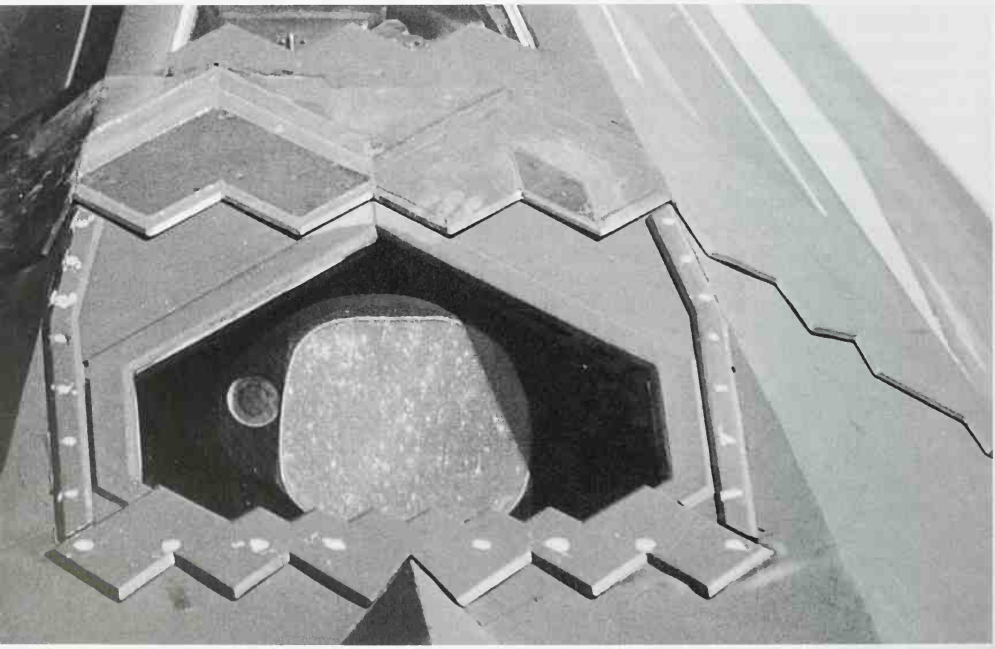
Antenna systems

Fixed flush, and retracting, blade antennas are installed on the aircraft to provide transmission and reception of necessary signals for operational requirements. The UHF communication system (AN/ARC-164V), consists of two retractable antennas, one upper the other lower, and provides amplitude-modulated, two-way radio communication with other similarly equipped aircraft or ground stations. With a normal line-of-sight range of 220 nm (408 km; 254 miles), communications can be conducted on one of 20 preset channels, or on any one of 7,000 manually selected frequencies.

The Have Quick (HQ) system provides normal and anti-jamming mode ultra-high frequency (UHF) communications by frequency hopping. Because the particular frequency in use at any instant depends on a precise time-of-day, all participating HQ UHF radios must have synchronised clocks. For additional security, the system also uses a word-of-the-day (WOD) made up of up to six three-digit segments and one of three frequency nets: A-Nets, Sectionalized A-Nets and T-Nets – A-Nets are used in operational situations.

The F-117 is also equipped with a secure voice communications system (KY-58) which is used with the UHF communications system to provide normal (plain) and cipher (coded) communications. The aircraft is also provided with an identification system, namely the AN/APX-101; this system includes two upper and lower retractable antennas and five operating modes, namely modes 1, 2 and 4 for tracking and identification purposes and modes 3/A and C for tracking and altitude reporting.

The newer F3 IRADS turret houses an improved laser. *(Paul F. Crickmore)*



Environmental control system

The environmental control system (ECS) air-conditioning and pressurisation functions to provide temperature controlled, pressure-regulated air for heating, cooling, ventilating, canopy defogging, cockpit pressurisation, canopy sealing, *g*-suit pressurisation, fuel tank pressurisation and electronic equipment cooling. Engine bleed air is directed through a turbine compressor and air-to-air heat exchangers where it is cooled by ram air. Conditioned air enters the cockpit, having been modified according to signals received from temperature sensors and from a manually operated control panel, to automatically control the cockpit temperature. Air pressurisation is provided by the pressurisation system for control/operation of some of the ECS, the canopy seal, *g*-suit and fuel tanks. Pressure in the cockpit is controlled automatically according to a predetermined schedule. A cockpit pressure safety valve relieves pressure if ever the cockpit pressure exceeds ambient pressure by 27.2 kPa (5.4 psi). The canopy seal is inflated/deflated with the mechanical locking/unlocking of the canopy.

Oxygen system

A five-litre (1.32-US gal) liquid oxygen system provides breathing oxygen to a diluter demand oxygen regulator. The regulator provides for selections of normal diluted oxygen and 100 per cent oxygen. Oxygen duration varies depending upon altitude, regulator settings and usage. The emergency oxygen system consists of a high-pressure bottle and a regulator mounted on the side of the ejector seat and is activated automatically upon ejection or manually by tugging a green ring located on the left side of the seat.

Ejection seat

The pilot of an F-117A sits in an ACES II ejection seat. This zero speed/zero altitude seat's mode of operation depends upon the aircraft's speed and altitude. Seat ejection is initiated by pulling ejection handles on the side of the seat. This retracts the shoulder harness and locks the inertia reel, fires initiators for canopy jettison and ignites the canopy removal rockets. As the seat leaves the aircraft, lanyards fire two seat-ejection initiators. A rocket catapult propels the seat from the cockpit, and the emergency oxygen is activated. The recovery sequencer selects the correct recovery mode based on pitot sensor inputs, and ignites the stabilisation package and the trajectory divergence rocket. If the ejection sequence was initiated with the aircraft travelling above 250 KIAS, initiation of the drogue gun, for seat stabilisation, occurs.

Updates

In 1984, the F-117's avionics architecture was the subject of a three-phase Offensive Capability Improvement Programme (OCIP). Phase I, the weapon system computational subsystem (WSCS) upgrade programme, was initiated to replace the Delco M362Fs with IBM AP-102 MIL-STD-1750A computers. These new units boasted the capability of 1 million instructions per second, 16 bit CPU with 128 k words of 16 bit memory expandable to 256 k – it is a repackage version of that used in the Space Shuttle.

The AP-102s are the same in number, and address the same disciplines as the Delcos and are nominally assigned to execute the appropriate operational flight programme as the W-WSC, the N-WSC and the X-WSC. The W-WSC is the system controller and data-integrator; it drives the primary displays and provides all the weapon delivery functions and is therefore a prime computer. The N-WSC provides precision inertial navigation, which, due to the very limited sensors carried by the aircraft is critical for most missions, therefore it too is a prime computer. The X-WSC computer can be used as a back-up for either of the other two.

The increased onboard computational power has made possible a number of new capabilities, the first of these being the successful deployment of the GBU-27 laser-guided bomb (LGB), together with the ability to perform dual-bay weapon deliveries.

Phase II of OCIP afforded greater situational

awareness, and reduced pilot workload, by allowing a 4D Flight Management System to fly complex profiles automatically. It features speed and TOT control; also included in this phase was the installation of colour multipurpose display indicators (CMDIs) and a digital tactical situation display or moving map; a new data entry panel, a display processor, an auto throttle system and a pilot-activated automatic recovery system (PAARS).

The two CMDIs replaced the MDIs and perform the same functions in addition to providing the moving map display. This latter provides a capability to monitor the aircraft's route of flight, update navigation, view threat locations and highlight high terrain features. There are two modes of operation: automatic, where the aircraft reference symbol follows the route of flight and manual, where a switch on the throttle is used to move around the map. Using the two-position map database switch provides a choice of paper map (PMAP), which consists of a digitised database taken from photocopying maps such as the TPC, or the DMAP (a database from the Defence Mapping Agency's digital files). The latter can be altered to meet special needs such as highlighting certain terrain, while the former cannot. A maximum of ten threats at any one time can appear on the map display and they are characterised as follows:

Q: Acquisition	4: SA-4
TR: Track	5: SA-5
HF: Height finder	6: SA-6
GC: Ground control	8: SA-8
C: Crotale	10: SA-10
R: Roland II/Rapier	11: SA-11
H: HAWK II/HAWK	12: SA-12
A: 23, 30, 57, 76 or 130 mm	N1: SA-N-1
	N3: SA-N-3
E: Early warning	N4: SA-N-4
2: SA-2	N6: SA-N-6
3: SA-3	N7: SA-N-7

PAARS was installed as a result of the fatal F-117A accidents, where spatial disorientation was a contributing factor. Upon pilot command, the autopilot, even if not engaged, commands the flight control system and auto throttles to fly a pre-programmed set of manoeuvres, based upon entry attitude and airspeed, to recover the aircraft to straight and level flight.

OCIP Phase III saw the replacement of the ageing SPN-GEANS INS system, with a new Honeywell H-423/E ring laser gyro (RLG) which was supplemented by a Rockwell-Collins global positioning system (GPS), thereby giving rise to the title RNIP plus. The new INS reduces alignment time from 43 minutes for SPN-GEANS, to just 9 minutes, and considerably enhances overall reliability, increasing the mean time between failures from 400 to 2,000 hours. The H-423 may not boost enhanced accuracy (still believed to be 0.12 nm/0.22 km/0.14 miles/h), however, when used in association with GPS, the system represents a significant advance in navigational accuracy.

A post OCIP Phase III F-117A cockpit can be identified by the active liquid crystal display incorporated into its HUD. The right CMDI can display primary flight data, but operational aircraft utilise this display for HSI, moving map displays or access to status and maintenance pages. If 'attack mode' is selected on the HUD, the display automatically cues the weapons arming page. During IRRCA evaluations the central IR sensor display, seen here, was removed and replaced with a color multifunctional display (CMFD), taken from an MH-53 helicopter. *(Lockheed Martin)*

Appendix 1. Weapons

All weapons carried by the F-117A are secured to a unique, hydraulically lowered trapeze. This dates back to the aircraft's initial design specification, which stipulated that it should be capable of hauling two of any weapon types in the USAF inventory. This being the case, the F-117A is, at least in theory, capable of employing target-acquiring weapons such as Maverick, AIM-7, -9 and -120 and even minigun pods; although no evidence is known to exist that would suggest that any of these weapons were even trialled.

At IOC, the originally prescribed precision guided munition (PGM) for the Nighthawk was the GBU-10 LGB. In its F-117A application, this weapon originally employed a 2,000-lb (907-kg) Mk 84 warhead and a Paveway II guidance unit. The guidance unit controls the weapon's trajectory via commands sent to four canards. This early guidance unit utilised harsh full deflection commands that often led to over correction, which in turn led to a loss of the weapon's energy and a failure to achieve optimum trajectory. The net result was that even if the weapon reached its target, it often had a high AoA, low impact velocity and poor impact angle. A PGM initiative produced a new 2,000-lb penetrating warhead known as BLU-109. This new warhead is used with a variety of guidance systems, including the more advanced Paveway III. Uniquely, the F-117A uses the GBU-27 LGB, which, in its standard form employs a Mk 84 warhead and in GBU-27A form totes the BLU-109. GBU-27 is generally similar to the

The GBU-27 (right) completed certification testing in late 1988, while new weapons under test include JASSM (above). *(Lockheed Martin)*

standard GBU-24, but has 'clipped' canards and Paveway II wings to allow it to fit into the F-117's weapons bay. A shorter adaptor collar is used between the warhead and guidance unit for a similar reason. The first weapons accuracy test was conducted on 28 May 1987, by Jim Dunn flying Aircraft 783. The inert weapon scored a direct hit on the target, a 55-US gal (208-litre) barrel, actually splitting in half! Latterly, tests have been conducted utilising the Lockheed Martin AGM-158 JASSM (Joint Stand-off Air-to-Surface Missile), the Boeing JDAM (Joint Direct Attack Munition) and the Raytheon AGM-154 JSOW (Joint Stand-Off Weapon).

Appendix 2. Individual Aircraft Histories

Serial Number Lot 1	First Flight Date	Pilot	AF Delivery	Remarks
79-10780	18/6/81	Hal Farley	N/A	First air refuelling 18/11/81 Last flight 30/6 or 1/7/85 (308 hours)
781 (Performance)	24/9/81	Dave Ferguson	N/A	First fully coated flight 30/12/81 or 1/1/82 First weapons release 7/7/82 Rudder loss 25/9/85 500 KEAS Door open 2/87 17/7/91 to Wright-Patterson AFB Museum (522 hours)
782 (Avionics)	18/12/1981	Tom Morgenfeld	N/A	First TAC flight 3/3/1982 First auto weapon separation17/12/82 12/6/91 temporary storage 7/92 began DARPA IR coating evaluations
783 (RCS)	7/7/1982	Tom Morgenfeld		6/83 signature tests begin 9/84 US Navy evaluation began 2/85 radar antenna tested 4/86 night vision goggles 3/89 turned over to USAF (830 flight hours) 31/8/92 LO antenna 5/93 painted grey

Serial Number	First Flight Date	Pilot	AF Delivery	Remarks
784 (IRADS)	10/4/82	Bob Riedenauer	N/A	First IRAD laser fire 5/82 20/9/83 temporary storage 8/8/85 first radar flight 6/87 dual door completes 500 KEAS 25/5/89 first composite rudder installation complete 18/7/89 first composite rudder flight 7/90 complete 600 flight hours 19/6/91 drops CBU-102
Lot 2				
79-10785 or 79-0785	20/4/82	Bob Riedenauer	scheduled 16/6/82	Aircraft crashed on take-off, Bob Riedenauer survived but badly injured
80-0786	15/7/82	Hal Farley	2/9/82	24 combat missions in the Gulf War
787	20/7/82	Hal Farley	23/8/82	
788	8/9/82	Tom Morgenfeld	22/10/82	
789	27/10/82	Hal Farley	17/11/82	31 combat missions
790	11/11/82	Skip Holm	11/12/82	30 combat missions
791	22/11/82	Skip Holm	13/12/82	33 combat missions
Lot 3				
81-10792	9/11/82	Skip Holm	22/12/82	Crashed 11/7/86, pilot Maj. Ross E. Mulhare killed
793	20/1/83	Skip Holm	1/2/83	33 combat missions Crashed 14/9/97, pilot Maj. Bryan Knight ejected safely
794	4/3/83	Skip Holm	15/4/83	35 combat missions
795	9/6/83	Hal Farley	9/9/83	
796	23/6/83	Tom Morgenfeld	4/8/83	29 combat missions
797	3/8/83	Tom Morgenfeld	31/8/83	8 combat missions
798	25/8/83	Dave Ferguson	3/10/83	34 combat missions
Lot 4				
82-0799	22/9/83	Dave Ferguson	28/10/83	21 combat missions
800	10/11/83	Hal Farley	7/12/83	
801	21/12/83	Tom Morgenfeld	15/2/84	38 combat missions Crashed 4/8/92, pilot Capt. John B. Mills ejected safely
802	7/3/84	Dave Ferguson	6/4/84	19 combat missions
803	8/5/84	Hal Farley	22/6/84	33 combat missions
804	25/5/84	Dave Ferguson	20/6/84	
805	5/7/84	Tom Morgenfeld	3/8/84	
806	20/8/84	Dave Ferguson	12/9/84	39 combat missions
Lot 5				
83-0807	13/9/84	Dave Ferguson	28/11/84	14 combat missions
808	29/10/84	Dave Ferguson	20/12/84	37 combat missions
809	3/1/85	Dave Ferguson	16/4/85	
810	18/1/85	Dave Ferguson	14/2/85	26 combat missions

Serial Number	First Flight Date	Pilot	AF Delivery	Remarks
Lot 6				
84-0811	8/3/85	Tom Morgenfeld	29/3/85	33 combat missions
812	1/5/85	Dave Ferguson	12/6/85	42 combat missions
Lot 7				
85-0813	7/6/85	Hal Farley	10/7/85	35 combat missions
814	26/7/85	Hal Farley	5/9/85	34 combat missions
815	13/9/85	Hal Farley	31/10/85	Crashed 14/10/87, pilot Maj. Michael C. Stewart killed
816	30/10/85	Tom Morgenfeld	20/12/85	39 combat missions
817	9/1/86	Dave Ferguson	28/2/86	18 combat missions
818	11/2/86	Hal Farley	22/5/86	38 combat missions
819	14/4/86	Dave Ferguson	24/4/86	On 11/6/86 this aircraft became the first to receive a coating of RAM via robotic spray 30 combat missions
820	2/5/86	Dave Ferguson	19 Jun 1986	
Lot 8				
86-0821	20/6/86	Tom Morgenfeld	1/8/86	32 combat missions
822	18/8/86		18/9/86	
823	7/10/86	Dave Ferguson	4/12/86	
84-0824	13/11/86	Dave Ferguson	17/12/86	
825	29/1/87	Tom Morgenfeld	25/3/87	33 combat missions
826	2/3/87	Dave Ferguson	25/3/87	29 combat missions
827	7/4/87	Hal Farley	18/5/87	
828	15/5/87	Dave Ferguson	17/6/87	
Lot 9				
85-0829	10/7/87	Hal Farley	27/11/87	23 combat missions
830	3/9/87	Hal Farley	27/11/87	31 combat missions
831	20/10/87	Tom Morgenfeld	27/11/87	This aircraft was chosen for the first OCIP upgrade, making its first OCIP flight on 1/12/88. It went on to become the testbed aircraft of the fleet
832	10/12/87	Tom Morgenfeld	11/2/88	30 combat missions
833	19/2/88	Dave Ferguson	25/5/88	30 combat missions
834	29/4/88	Tom Morgenfeld	27/5/88	34 combat missions
835	30/6/88	Tom Morgenfeld	15/8/88	26 combat missions
836	21/9/88	Tom Morgenfeld	19/10/88	39 combat missions
Lot 10				
86-0837	8/12/88	Hal Farley	22/2/89	31 combat missions
838	17/3/89	Hal Farley	24/5/89	36 combat missions
839	14/6/89	Hal Farley	14/8/89	39 combat missions
840	12/9/89	Jim Thomas	1/11/89	32 combat missions
Lot 11				
88-0841	7/12/89	Jim Thomas	8/3/90	On 8/3/90 this aircraft received the first production composite rudder 18 combat missions
842	13/3/90	Jim Thomas	28/3/90	33 combat missions

Serial Number	First Flight date	Pilot	AF Delivery	Remarks
843	11/5/90	Hal Farley	27/6/90	On 12/7/90 this aircraft took part in a final delivery ceremony for the F-117 33 combat missions
Lot 10+				
Insurance spares: fuselage/wings				Fuselage 5/4/90 Right wing 15/5/90 Left wing 8/6/90 Right wing 29/6/90 Left wing 9/8/90

Combat missions refer to those flown during *Desert Storm*

Appendix 3. Model Kits and Further Reading

Manufacturer	Scale	Remarks
Academy	1:72	F-117A Stealth Fighter
Academy	1:48	F-117A Stealth Fighter
Airfix	1:72	F-117 Stealth
CDC	1:48	F-117 Stealth Fighter (metal kit)
Hasegawa	1:72	F-117A Nighthawk 'Stars & Stripes'
Hasegawa	1:72	F-117A Nighthawk with GBU-27 guided bombs
Hobbycraft	1:48	F-117A Stealth Fighter
Italeri	1:72	F-117A Stealth
Italeri	1:32	F-117 Stealth Fighter
Italeri	1:48	F-117A Stealth
Monogram	1:48	F-117A Stealth Fighter
Revell	1:144	F-117 Stealth Fighter
Revell	1:48	F-117 Nighthawk
Revell	Unknown	F-117 Stealth
Tamiya	1:48	F-117A Nighthawk
Testors	1:32	F-117A Stealth Fighter

Further reading

F-117 Nighthawk, Paul F. Crickmore & Alison J. Crickmore, Motorbooks International

Combat Legend Lockheed SR-71 Blackbird, Paul F. Crickmore, Airlife Publishing Ltd

F-117 Stealth In Action, Squadron Signal

F-117 Nighthawk Walk Around, J. Goodall, Squadron Signal

Appendix 4. Glossary

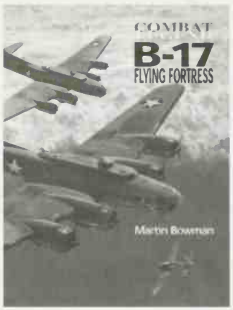
AAA	Anti-Aircraft Artillery
ABDR	Advanced Battle Damage Repair
AFFTC	Air Force Flight Test Center
APU	Auxiliary Power Unit
ARCP	Air Refuelling Control Point
ATA	Advanced Technology Aircraft
A/R	Air Refuelling
BSAX	Battlefield Surveillance Aircraft Experimental
CAP	Combat Air Patrol
cg	Centre of Gravity
CIA	Central Intelligence Agency
Comint	Communications Intelligence
CTF	Combined Test Force
DARPA	Defense Advanced Research Projects Agency
DLIR	Downward-Looking Infra-Red
DO	Director of Operations
ECM	Electronic Countermeasures
ECS	Environmental Control System
Elint	Electronic Intelligence
EPU	Emergency Power Unit
FBW	Fly-by-wire
FCF	Functional Check Flight
FES	Flutter Excitation System
FLIR	Forward-Looking Infra-Red
FMS	Flight Management System
FPA	Flight Path Accelerator
FSD	Full Scale Development
FWS	Fighter Weapons Squadron
GCI	Ground Controlled Intercept
GFE	Government Furnished Equipment
HAC	House Appropriated Committee
HASC	House Armed Services Committee
IES	Inertial Exciter System
IFR	Instrument Flight Rules
IOC	Initial Operational Capability
IOC	Intercept Operation Center
IRADS	Infra-Red Acquisition and Designation System
LGB	Laser-Guided Bomb
MDI	Multi purpose Display Indicators
MDPS	Mission Data Planning System
NAS	Naval Air Station
NATO	North Atlantic Treaty Organisation
OCIP	Offensive Capability Improvement Programme
ORI	Operational Readiness Inspection
OT&E	Operational Test & Evaluation
PAARS	Pilot-Activated Automatic Recovery System
RAF	Royal Air Force
RAM	Radar Absorbing/Attenuating Material
RAS	Radar Absorbing Structure
RATSCAT	Radar Target Scatter
RCS	Radar Cross Section
RLG	Ring Laser Gyro
RNIP	Ring Laser Gyro, Navigation Improvement Programme
RSS	Relaxed Static Stability

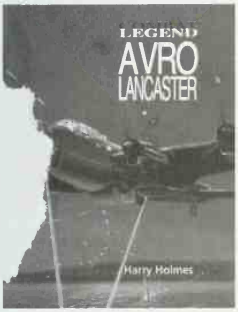
SAC	Senate Appropriations Committee
SAM	Surface-to-Air Missile
SAR	Special Access Required
SASC	Senate Armed Services Committee
SEAD	Suppression of Enemy Air Defenses
SOC	Sector Operations Center
SPEAR	Strike Projection Evaluation and Anti-Air Research
SPO	Special Project Office
TAC	Tactical Air Command
TFW	Tactical Fighter Wing
TOT	Time Over Target
TTO	Tactical Technology Office
UCAV	Uninhabited Combat Aerial Vehicle
UFC	Unified Fuel Control
VFR	Visual Flight Rules
VLO	Very Low Observable
WBI	Weapons Bay Improvement
WSC	Weapon Systems Computer
WSCS	Weapons System Computational Subsystem
WSO	Weapons Systems Officer
XST	Experimental Survivable Testbed

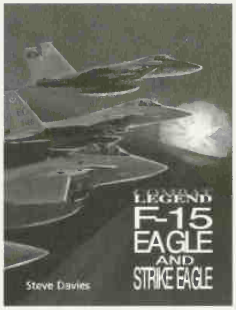
The Nighthawk is likely to retain a prominent place within the USAF inventory for some time to come. However, it is conceivable that some of the type's role could eventually be taken over by the less specialised Lockheed Martin F/A-22 Raptor and F-35, and that it might one day be replaced by a stealthy UCAV. *(Lockheed Martin)*

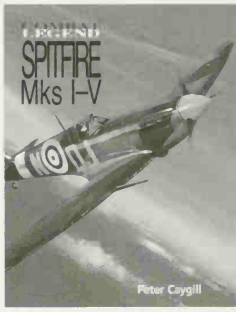
Index

COMBAT LEGENDS









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The F-117 has proved itself to be an important weapon wherever the USA has become involved in actions against dictators and terrorist regimes. Forty-two aircraft flew from Saudi Arabia to attack targets in Iraq and occupied Kuwait. In 1999 the first loss of an F-117 occurred in Operation *Allied Force*. There is little doubt that whenever the US Air Force is called into action, the Nighthawk is summoned to the front line and beyond. It served for many years during the Cold War until superseded by satellite technology.

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